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WAR MACHINE

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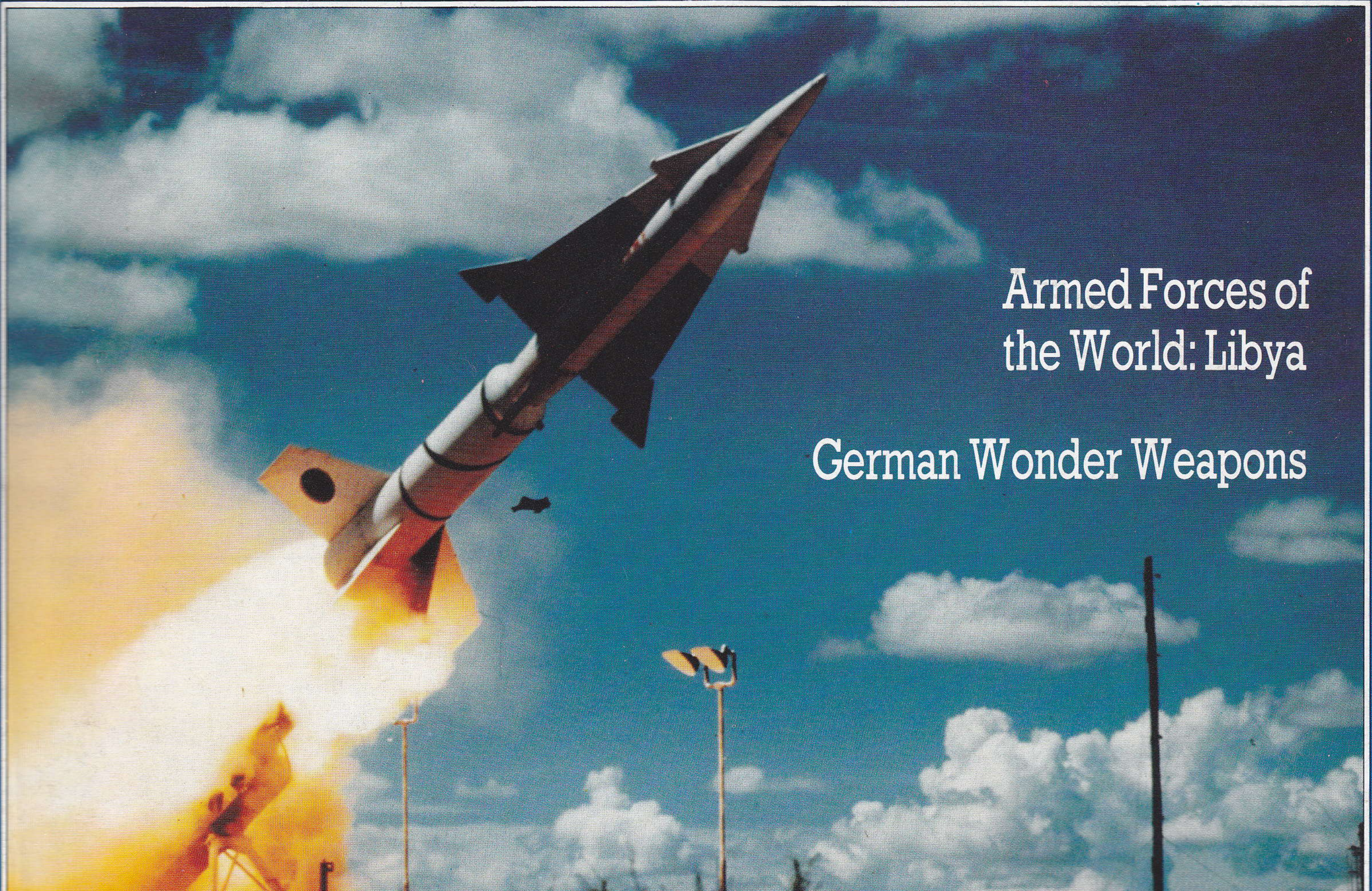

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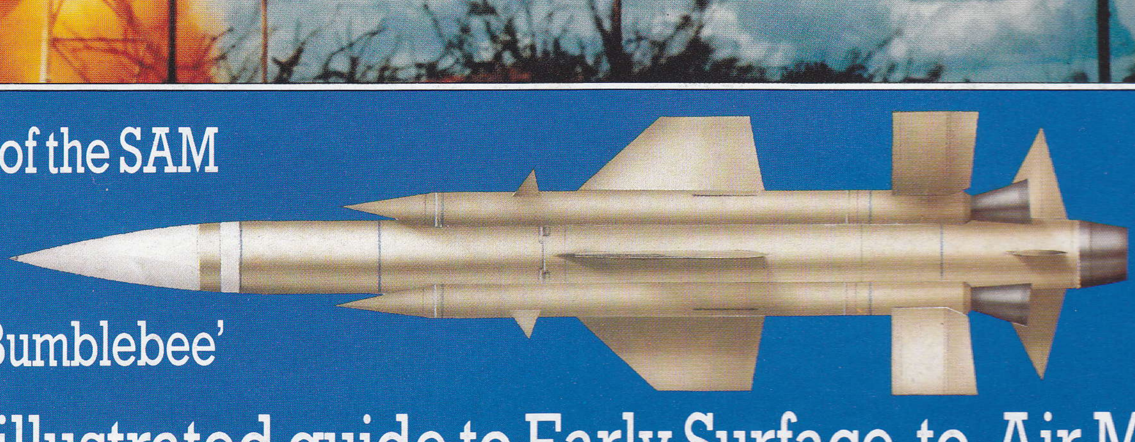

Project 'Bumblebee'

A fully illustrated guide to Early Surface-to-Air Missiles

WAR MACHINE

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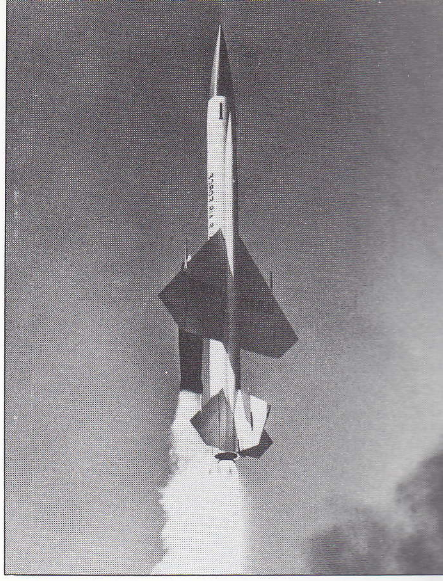
Early Surface-to-Air Missiles



Bomarc was a typical product of the technological explosion that was missile development in the 1950s. At one stage, such missiles were thought to be capable of replacing manned interceptors, although this was to prove a costly mistake for some governments.

The development of surface-to-air missiles in the years following the end of World War II has wrought a considerable change upon the modern battlefield. Evading the missile defence has become a prime requirement of any modern aircraft mission.

Surface-to-air missiles (SAMs) developed from two very different World War II problems. On land, it is hardly surprising that Germany devoted enormous resources to the development of a staggering variety of projects, whereas the Allies ignored the potentials of the new weaponry. After all it was Germany that was at the receiving end of an overwhelming assault from the air at the same time as the technology was emerging to deal (at least in potential) with the threat.

At sea it was the Allies, and most specifically the Americans, who needed a more efficient means to handle the *kamikaze* threat than the carriage of as many 20-mm and 40-mm guns as could be crammed onto the decks of ships. This provided the initial impetus for the immensely successful American naval SAM programme of the late 1940s and early 1950s, which was to become the foundation for the US Navy's fleet missile defence in the 1980s.

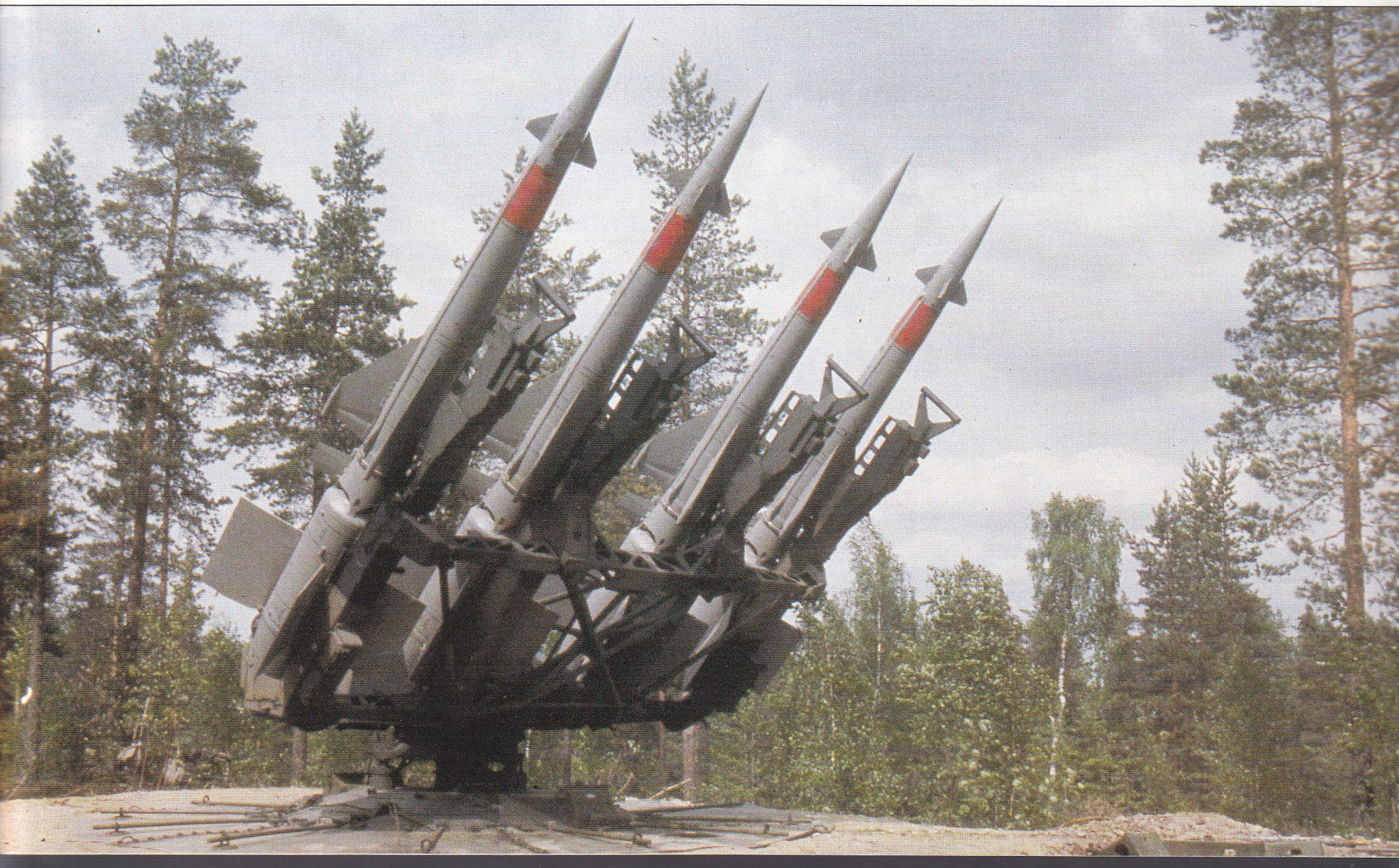
The first missiles were guided by an operator using radio signals to steer a missile visually towards the target. This CLOS (Command to Line Of Sight) system is still fairly important today for short-range missiles, although it is vulnerable to electronic countermeasures.

The most important method of guidance in these early missiles, and one which was to be used in some of the most widely deployed systems, involved the use of a pencil radar beam to track the target and a second beam to track the missile. Sometimes guidance instructions were passed in coded pulses along the radar beam itself, and sometimes by a UHF beam linked to the missile tracking radar.

The other important innovation came with the development of the proximity fuse, much work having been done by the Germans although it was the American radio proximity fuse for gun-launched AA shells which pointed the way for the future.

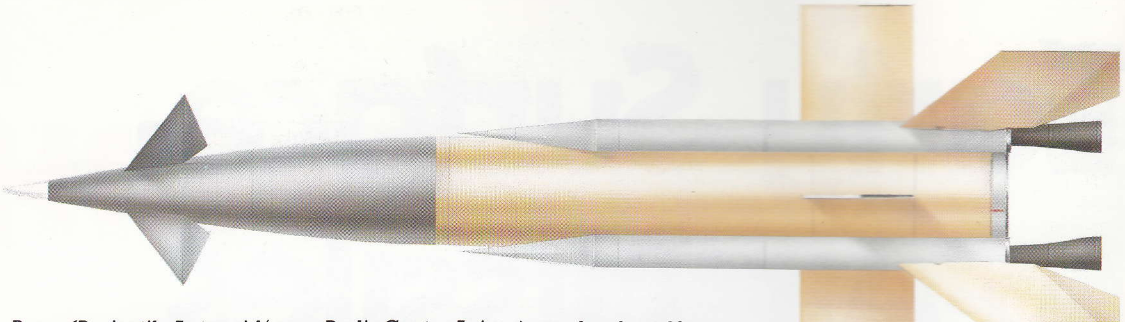
The most important achievement of the SAM was not to become evident until the beginning of the 1960s, when the destruction of an American Lockheed U-2 spyplane over the USSR proved that altitude, however high, was no guarantee of safety. The day of the high-flying strategic bomber was done, and from that time penetration of enemy territory had to be envisagd at lower and lower levels. The SAM had made its indelible mark on the battlefield.

Given the NATO designation and reporting name SA-3 'Goa', this first-generation Soviet-built SAM has been exported to a number of countries, including Finland, a quadruple launcher of the Finnish army being seen here. It has also been adapted by the Soviet navy, and for many years has provided fleet air defence.

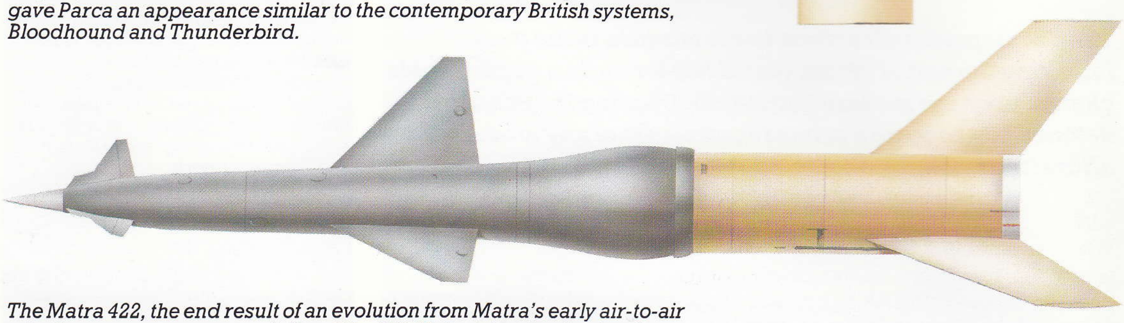


FRANCE

French SAMs



Parca (Projectile Autoguidée par Radio Contra Avions) was developed by a large consortium which included the French army. The wraparound boosters gave Parca an appearance similar to the contemporary British systems, Bloodhound and Thunderbird.



The Matra 422, the end result of an evolution from Matra's early air-to-air missile programme, was a victim of the NATO decision to adopt and co-produce the American designed HAWK system (HAWK being an acronym for Homing All the Way Killer).

French industry was quick to recover from the ravages of World War II and occupation. Indeed, the French armaments industry worked, albeit reluctantly, on the behalf of its conquerors, and so gained access to a certain amount of German military technology. Nevertheless, the missile programmes which eventually emerged owed more to native design and American example than to German achievements.

The first SAM programme came about as a side product of Matra's M.04 air-to-air missile. Developed from 1948 and first flying in 1950, the M.04 was later developed into an enlarged tandem-boosted canard-winged surface-launched system. Called the **R.042**, this surface-to-air missile was developed until the mid-1950s. The first operational French SAM (and one of the first West European missiles of this type), the **Matra R.422** first flew in November 1954. Derived from the R.042, the type achieved IOC (Initial Operational Capability) in late 1958, but by that time France (then a full member of NATO) had come to an agreement with West Germany, Belgium, the Netherlands and Italy to adopt and co-produce the American HAWK system. The Matra missile was cancelled. R.422 was tandem-boosted, with cruciform wing on both stages, and designed to deal with bombers travelling at up to Mach 2 and at altitudes of between 3000 and 20000 m (9,845 and 65,615 ft). The guidance was similar to the radio-command system used in the American Nike Ajax system.

At the same time, the French army was part of a large industrial team developing a different missile also using Nike Ajax style radio command guidance. **Parca**, an acronym derived from Projectile Autoguidée par Radio Contra Avions (radio-controlled anti-aircraft missile) was an impressive system of similar size to the R.422, and having some commonality in guidance hardware. Unlike the Matra design, boost was from four swept-fin wraparound solid rockets, making for a much more compact package on the ground. The tapered cylindrical body had rectangular cruciform fins and delta cruciform control surfaces farther forward. More than 120 missiles were fired between 1954 and 1958, at ranges such as Colomb-Béchar in Algeria, and from that latter year a number equipped a single regiment of the army until 1962, when the first HAWKs entered service.

Mention should also be made of the **SNCASE SE.4300**, which was the first guided missile in France to reach flight trials. It was used as a test vehicle for SAM components, and as a training missile for personnel of all three services.

Specification

Parca

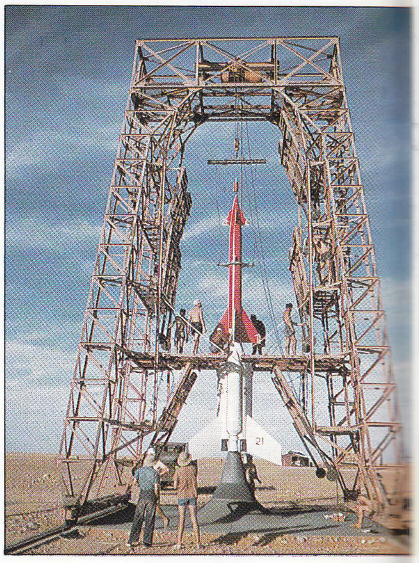
Type: medium-range land-based SAM

Dimensions: length 5.00 m (16 ft 5 in) or 5.48 m (17 ft 11.75 in) with boosters; span 1.60 m (5 ft 3 in)

Launch weight: 1100 kg (2,425 lb)

Performance: operating range 32 km (20 miles); maximum altitude 20000 m (65,615 ft)

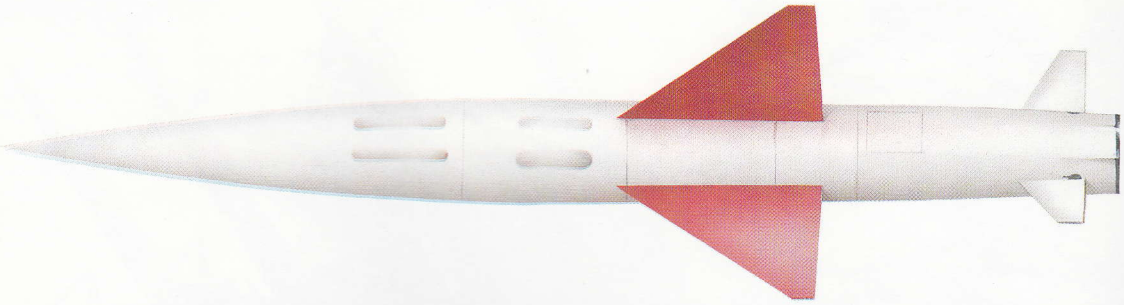
Warhead: probably continuous-rod HE with a proximity fuse



A Matra R.422 is prepared for firing at an Algerian range in 1955. It was very much a missile of the time, with guidance similar to the pioneering American Nike-Ajax. In common with most SAMs of the same generation, the Matra R.422 was a substantial piece of equipment, designed to handle the classic 1950s threat of bombers flying at high speed and altitude.

SWITZERLAND

RSC and RSD



The Swiss-developed RSC and RSD series of missiles were among the most advanced of all early SAMs, a batch being tested in the early 1950s by the US Air Force. The last of the series, the RSD 58, had a 50 per cent increase in performance without any increase in overall dimensions.

Developed as a commercial proposition by Contraves and Oerlikon, this overall Swiss project was astonishingly farseeing for its time. First steps were taken as early as 1947, when plans were set in motion to produce a liquid-propellant beam-riding guided missile that would be as portable as an average heavy artillery battery. The first flights were made in 1950, and extensive trial firings of this initial version were made in France and Switzerland over the next two years, and the system was put on the market as the **RSC-50**, the first SAM system to be offered for general sale.

In 1953, a batch of 25 missiles was evaluated by the USAF at Holloman AFB, New Mexico. These weapons were of the **RSC-51** type (the two figure number indicating the year in which development was completed) and were given the US designation **MX-1868**.

The first sales were made to the Swiss armed forces in 1954, others being sold to Italy (where the Italian subsidiary of Contraves manufactured them as the **MTG-CI-56, -57** and **-58**) and to Japan.

An improved version, designated **RSD-58**, of increased performance but with the same dimensions, followed. This was accompanied into service by a training missile (with a parachute recovery system instead of a warhead) designated **RSC-57**.

The RS series missiles were all liquid-fuelled beam-riding missiles with cruciform delta wings and small tail control surfaces. Propelled by a nitric acid/kerosene sustainer that gave approximately 1000-kg (2,205-lb) thrust for 30 seconds (RSC-57) or 45 seconds (RSD-58), the missiles achieved a maximum speed at burnout of Mach 1.8 in the earlier model and Mach 2.4 in the 1958 version. The wings were designed to slide fore and aft in slots in the missile body while in flight to compensate for trim changes as fuel was consumed. The tapered cylindrical missile was constructed from light alloys, bonded with Araldite.

An RSD-58 battery consisted of a battery command post, target-tracking radar, pencil-beam missile-control radar, and six twin missile launchers (capable of launching missiles at any angle between 10° and 90°) together with all the necessary power supply units.

Specification

RSD-58

Type: medium-range land-based SAM

Dimensions: length 6.10 m (19 ft 8 in); diameter 400 mm (15.75 in); span 1.35 m (4 ft 5.1 in)

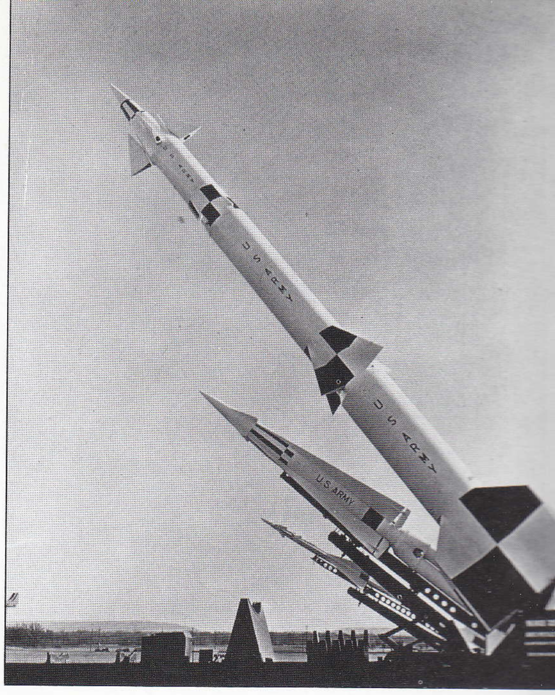
Launch weight: 460 kg (1,014 lb)

Performance: operating range 30 km (18.6 miles); maximum altitude 20000 m (65,615 ft)

Warhead: 40-kg (88-lb) HE with proximity fuse

The Rise of the SAM

The US Navy spearheaded the development of SAMs as a result of its experience of Japanese kamikaze attacks during World War II. Other services and other nations followed suit, none with more dedication than the Soviet Union, which seemed prepared to pay any price to possess an effective anti-aircraft system.



The US Army funded the Nike project which spawned three generations of SAMs: from back to front (in order of development) Ajax, Hercules and Zeus.

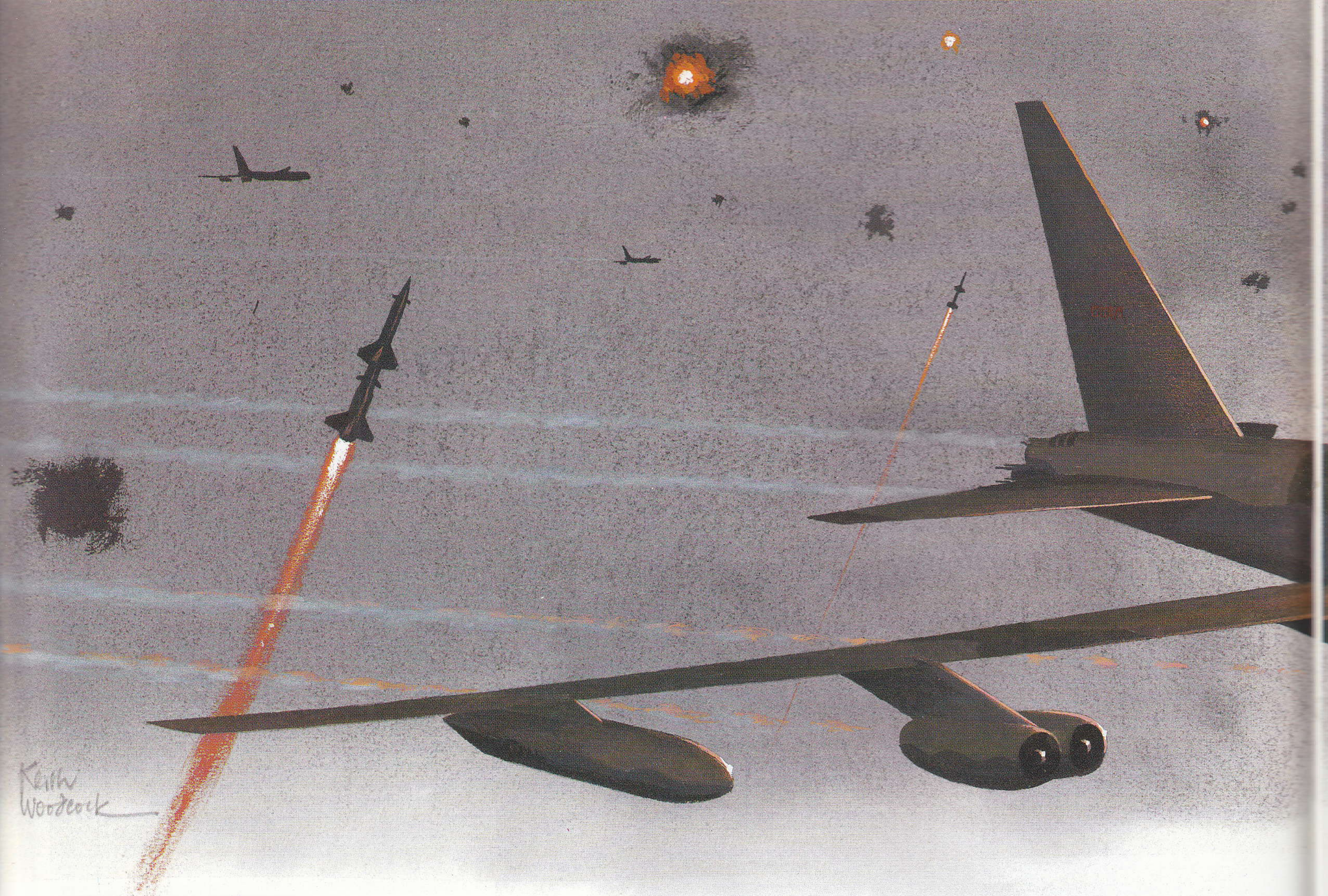
After World War II only the US Navy had a firm and aggressive SAM (surface-to-air missile) programme. Triggered off by the terrible feeling of helplessness in the face of *kamikaze* attack, the US Navy SAMs were taking shape in several forms. Boosted off ship launchers by rockets, they subsequently streaked into the sky propelled either by an internal rocket or an internal ramjet, with various forms of radar guidance.

The US Army had little need to think about SAMs in World War II, but in early 1945 it did start funding a project, called Nike 1 after a Greek goddess (pronounced Nikey). It did this largely because the SAM expertise of the US Navy worried the US Army that the rival service might even grab the plum job of SAM defence of the United States! On reflection it would have made more sense for the US Army to concern itself with mobile SAM systems that could move with its troops. Instead it developed Nike 1, later called Nike Ajax, as a colossal system involving thousands of tons of equipment distributed around giant fixed sites, many of the items being underground though completely unhardened against nuclear bombs.

The trouble with enormous weapon systems is that they tend to be permanent. They are costly to build, almost impossible to alter, and can critically influence the next generation. Thus, with 40 battalions deploying over 16,000 Ajax missiles, the next generation also had to be a Nike, and it was no easy task to develop the Nike Hercules SAM so that it fitted more or less into the same bases. The guidance radars, however, had to be replaced by far more powerful ones matched to the impressive flight performance of the fearsome Hercules missile, which could knock down targets 45720 m (150,000 ft) up at a range of 'more than 87 miles' (140 km).

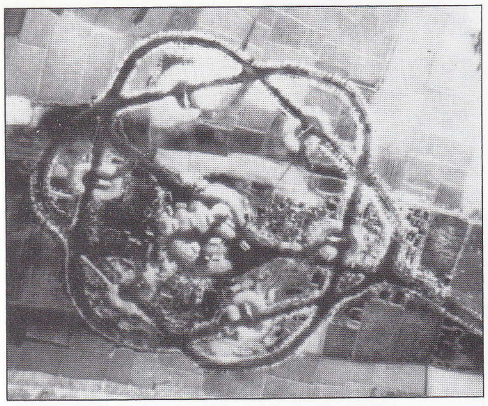
A broadly similar, but much cheaper, SAM was put into mass-production by the USSR. The V750 system, called SA-2 'Guideline' by NATO, used a missile midway between Ajax and Hercules in size, made since 1955 in numbers which seem to Western nations to be astronomic. The V750 system uses rather sophisticated radars to steer the missile to the same point in the sky as the radar centre of the target, and in the absence of countermeasures the missile is effective. On 1 May 1960 a single round destroyed the Lockheed U-2 of CIA pilot F.G. Powers, who subsequently stood trial in the USSR. Meanwhile the US technical press almost all followed 'the party line' in denying that any Soviet SAM could bring down a U-2. Powers' aircraft, it was said, had suffered a

The RAF's Bloodhound missiles have now been withdrawn from Germany and deployed along the British east coast. The SAMs adopted by all three British services during the 1950s proved disagreeably costly, partly because production totals were so low.



Linebacker

Great care was taken to avoid hitting civilian targets during the 1972 bombing of Hanoi. This involved early model B-52s, without modernized ECM, flying unmanoeuvring direct bomb runs and presenting SA-2s with the very target they were built to engage. However, intensive US suppression of SAM sites and flights by ECM aircraft resulted in only two per cent of the missiles finding their target.



A North Vietnamese SA-2 battery with five launchers visible is photographed from an RF-101, 25 miles north west of Hanoi in 1966. The site is 210 m×135 m (700 ft×450 ft). As soon as the North Vietnamese learned of the restrictions imposed on US pilots, they deployed their missiles near paddy dykes and built-up areas.

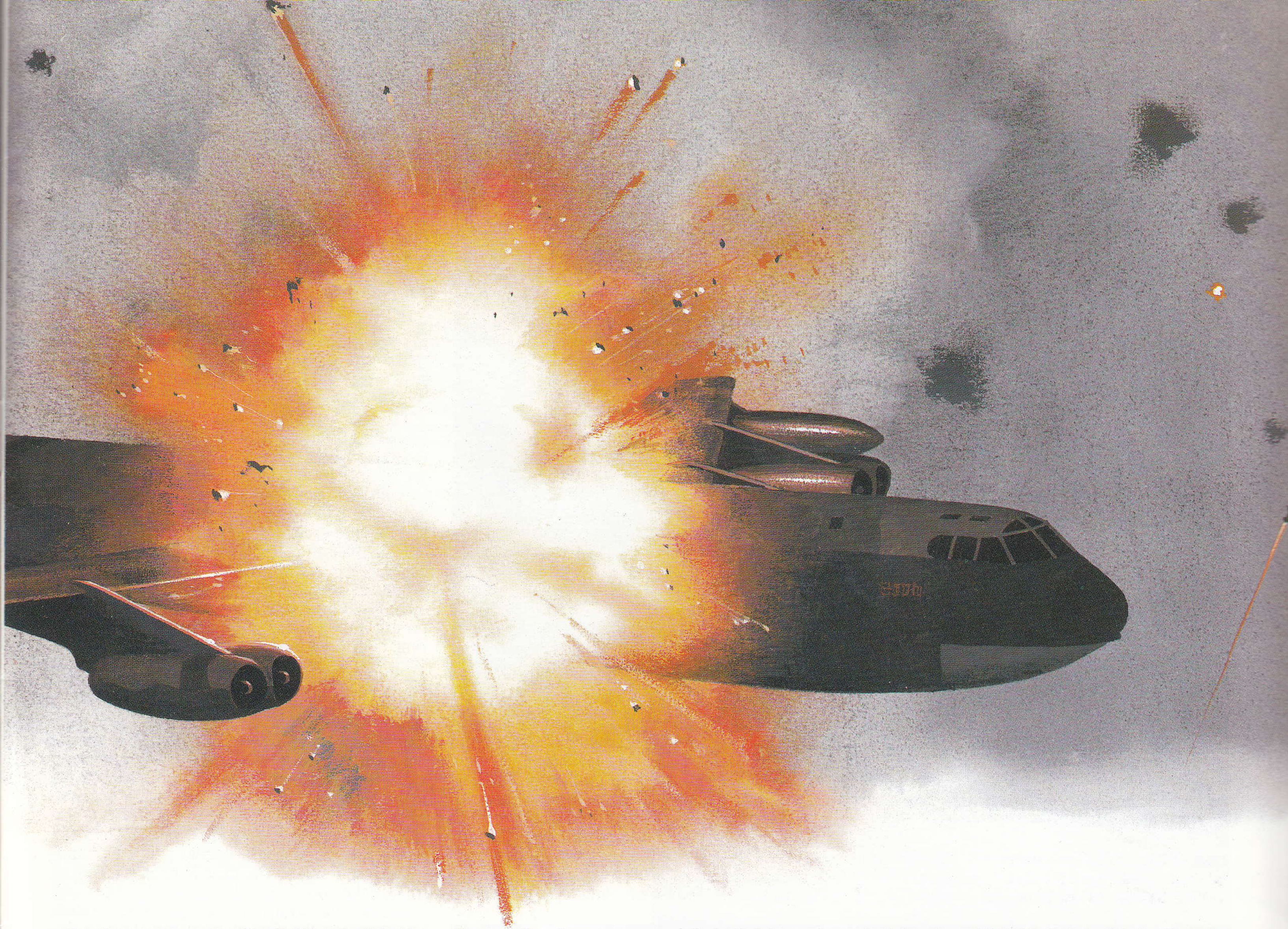
flameout and been forced to glide down to a much lower level, bringing it within range of the Soviet defences. This was pure wishful thinking by the Pentagon, though the motive was obscure. Perhaps it did not want to think the Soviets capable of building effective weapons, which is a very dangerous attitude! The magazine *Aviation Week* even appeared to take pride in the thought that the U-2 had spent years 'cruising far above the reach of Soviet SAM systems'. Today such nonsense has been forgotten, and the fact that an SA-2 destroyed the U-2 at its maximum cruising height has long been accepted.

In fact, the familiar V750 system was actually preceded by a much bigger SAM, called SA-1 'Guild' by the West, which should have dispelled for ever any suggestion that the USSR could not build advanced missiles. Much bigger than the V750, the SA-1 forms part of a network of radars, some of which can each track 30 targets simultaneously. The SA-1 has always been seen at major bases, deployed in formidable groups, whereas the V750 can travel with an army and quickly be set up to defend large areas. These, and the slightly later SAMs called SA-3 'Goa' (also used from ships) and SA-4 'Ganef' (a massive ramjet weapon carried on amphibious AFVs), all appear to have been completely successful weapons deployed in tremendous number, despite the awesome cost.

In the UK nothing much was done in the first five years after World War II. Then a different government was elected which did not share the view that defence was unimportant (and the outbreak of war in Korea in June 1950 put a huge spur to all defence programmes), and work went ahead on three large and costly SAM programmes. All were more or less similar in basic size and technology, but one was for the army, one for the Royal Navy and one for the RAF. The shipboard weapon, the Seaslug, was smallest, with a body diameter of 406 mm (16 in). It also differed in riding a radar beam to its target, and an odd feature was that it was blasted off its launcher by four large solid motors with flat noses arranged round the front of the missile. Though massive and cumbersome by comparison with today's SAMs, Seaslug was so well-engineered it soon achieved an SSKP (single-shot kill probability) of 92 per cent, when other SAMs were unable to reach 50 per cent.

Thunderbird

A cumbersome weapon that works is better than a neat one that does not, and this also applies to the army SAM, the Thunderbird. Originally codenamed 'Red Shoes', it grew into a mighty system needing large numbers of men, vehicles and ground installations. Everything, however, was air-mobile and most could be paradropped. The Thunderbird Mk 1 had semi-active homing guidance using a pulsed target-illuminating radar. The Thunderbird Mk 2, though no bigger, had much higher flight performance with a range out to 75 km (47 miles), and the CW (continuous-wave) radar gave much more accurate guidance against low-level targets or in the face of enemy jamming.

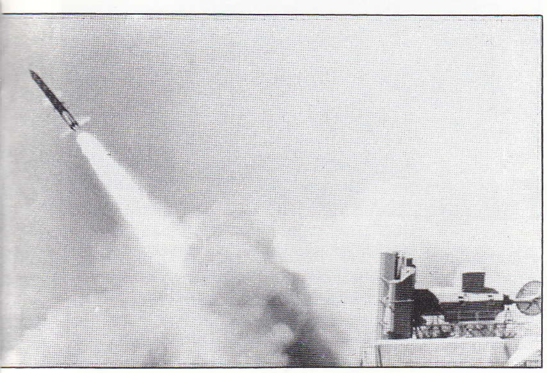


In the same way the RAF missile, the Bloodhound (original codename 'Red Duster') was developed in two marks, the Mk 2 having greater speed and range, and superior CW radar homing guidance. Deployed in multiple groups from more or less fixed sites, the Bloodhound has served the RAF (and export customers) very well indeed, and is still in use. The planned Bloodhound Mk 3, however, under full development from the mid-1950s as 'Blue Envoy', was cancelled in 1961, with nothing to replace it. What makes this much harder to understand is that just four years earlier, in April 1957, the then Minister of Defence, Duncan Sandys, announced that all future air defence would be by SAMs, and that therefore all manned fighters were being cancelled!

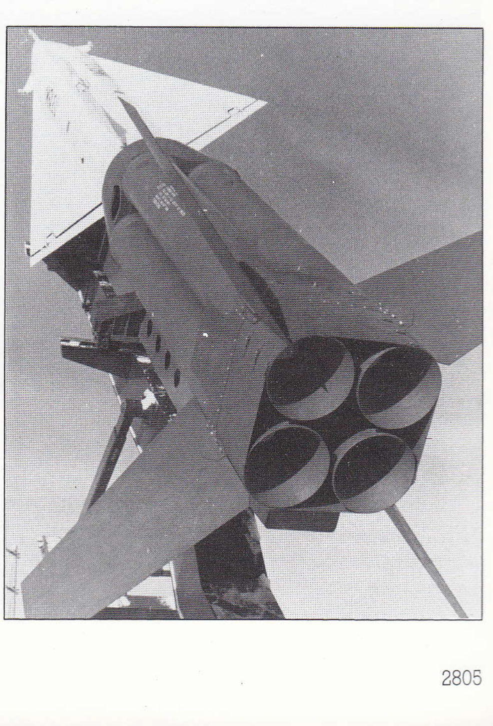
Though much smaller than the Soviet SAMs, these three British systems were costly, a fact not helped by the modest production totals. In an effort to provide simpler and cheaper defence Shorts at Belfast developed the smaller and more primitive Seacat late in the decade. By setting its sights low, in more senses than one, Shorts quickly created a system costing less than one-tenth as much as Seaslug, yet which could offer protection against fairly close or low-flying attackers to all ships down to the size of FPBs. The missile itself was small enough for the launchers to be loaded by hand, and customers were offered a choice of plain manual command guidance, using binoculars and a joystick, or various night and bad-weather radar links. As a result Seacat sold like hot cakes.

The same could be said of the HAWK (from Homing All the Way Killer), development of which began for the US Army in 1954. Compared with Seacat the HAWK system was a monster, and more than 25 times as expensive; but it was far better than anything else and soon sold to the USA's allies all over the world. The missile itself weighs about 626 kg (1,380 lb), a bit big for manual reloading, but absence of rivals has kept HAWK right in the forefront for over 30 years. Today, over 40,000 missiles later, improved versions are still in production, and some nations, such as Japan, are still deploying fresh launchers.

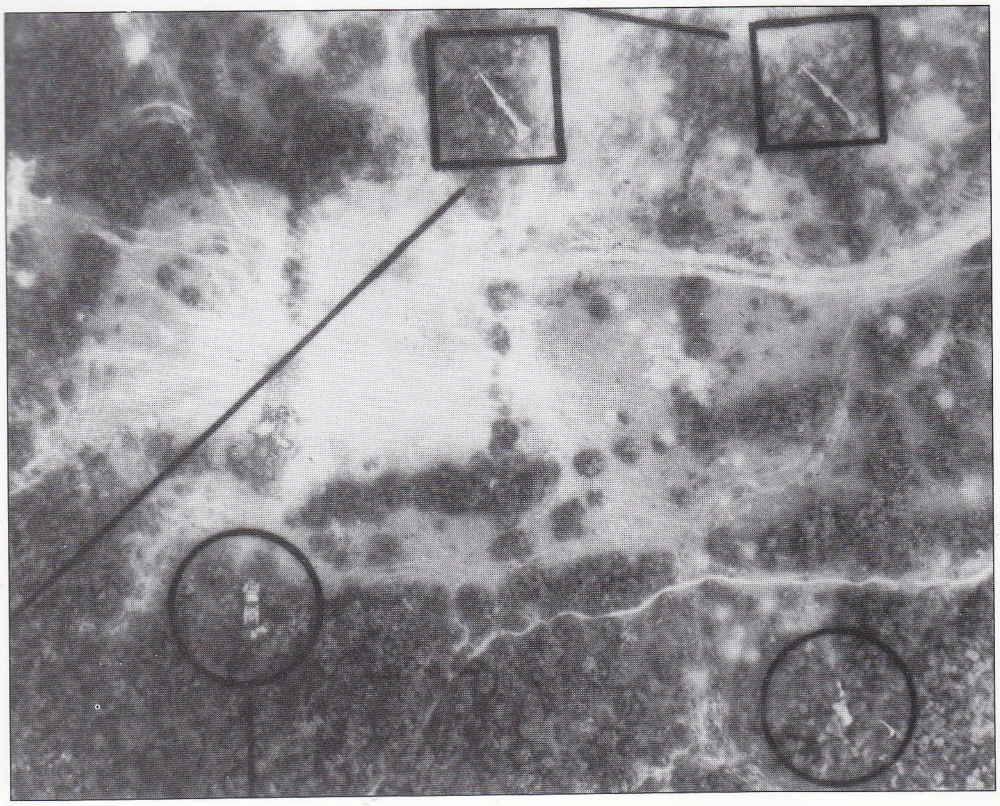
HAWK succeeded by being big and costly, but not too big and costly. The grandiose plans of the US Air Force, however, almost serve as an object lesson in how not to do it. A year after World War II the USAAF, as it then was, laun-



An Egyptian SA-2, modified from the Soviet original, is launched during an air defence exercise in March 1986, 26 years after it made its spectacular combat debut. On the right is the 'Fan Song' radar, modified to allow optical guidance.



The Hercules could destroy enemy aircraft over 130 km (80 miles) away, flying at 150,000 ft. Despite this, US sources refused to admit that the Soviets could do the same, and the fact that an SA-2 had destroyed Gary Powers' U-2 was hotly denied.

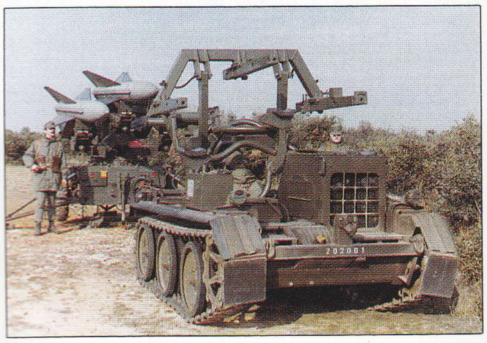


North Vietnamese SA-2s are seen from a US aircraft, this time with their transporters (squares mark the missiles; the trucks are circled).

ched three SAM programmes: MX-606 with Boeing, to reach out 56 km (35 miles) at 18290 m (60,000 ft); MX-794 with the University of Michigan, to reach 885 km (550 miles) at 152400 m (500,000 ft); and MX-795 with General Electric, again for 885 km (550 miles) at 152400 m (500,000 ft). MX-795 (Thumper) was terminated, and Boeing and the Michigan Aeronautical Research Center produced Bomarc, coining the name from their own name and initials. As described in this study Bomarc matured as big as a fighter, and its price was in fact several times greater than that of a North American F-86. Prompted by Duncan Sandys' policy in the UK, the Canadians scrapped their outstanding Avro Arrow interceptors, dealing their aerospace industry a blow from which it has never recovered, and bought Bomarcs which sat on their expensive launchers for just 10 years. They were scrapped in their turn (to be replaced by the McDonnell F-101 Voodoo interceptor bought secondhand from the USAF, the final touch of irony being that the F-101 had been rejected in 1953 when the Arrow design went ahead).

Perhaps even stranger is the story of what in the mid-1950s were called merely 'antis'. At that time the possibility of building ICBMs (intercontinental ballistic missiles) with city-destroying warheads had just become apparent. It was natural to try to develop an anti-ICBM missile, but the problems were gigantic. Throughout the 1950s and 1960s the US Army and a host of scientific and industrial contractors toiled to create a working ABM (anti-ballistic missile) system. At last, after expenditure greater than on any other weapon, the first ABM site was built and declared operational on 1 October 1975. On 2 October 1975 the whole site was officially deactivated, and it has remained deserted ever since. The only nation that doggedly pursued ABM programmes through to combat duty was, naturally, the USSR. Where weapons are concerned, roubles are never of any consequence, and the vast system known in the West simply as ABM-1B 'Galosh' became operational in 1968 after 12 years of effort. The system includes radars described as 'like three football fields lined up end-to-end and standing on their sides'. The missile itself is as big as a Peacekeeper ICBM! Perhaps more than any other single weapon, this gigantic system underscores the Soviet determination to deploy every kind of armament it considers it needs, no matter what the cost.

The only remotely comparable weapon system now planned in the West is the SDI (Strategic Defense Initiative). It remains to be seen whether the USA, with or without help from others, will show the same singleminded determination as the Soviets.

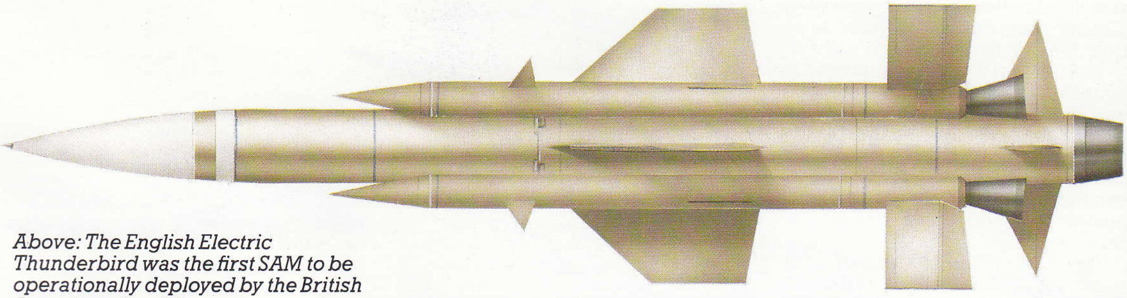


Above: Seen here in French service, HAWK has enjoyed immense success in the export market because of its cost-effectiveness. Some 40,000 missiles have been manufactured. Improved versions continue to be developed and fresh launchers are being deployed.

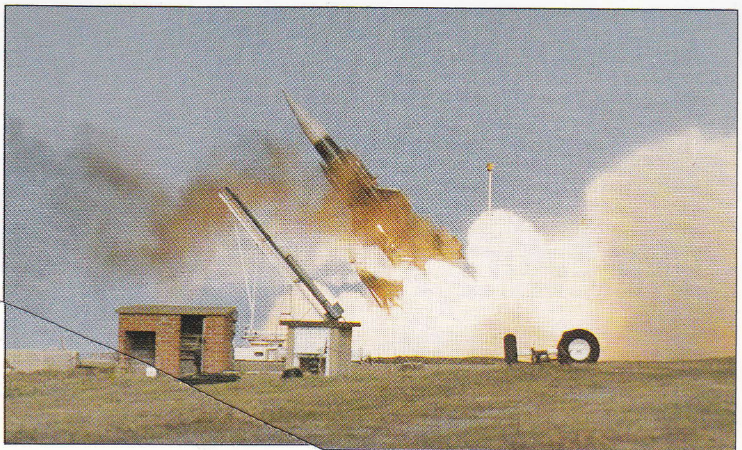
Left: Whatever their theoretical performance, expensive missiles met with consumer resistance, so Short Brothers in Belfast developed Sea Cat and its land-based counterpart, Tiger Cat, seen here.

UK

Thunderbird



Above: The English Electric Thunderbird was the first SAM to be operationally deployed by the British Army. In spite of the wraparound boosters, which reduced the length of the missile, Thunderbird was, like its contemporaries, a somewhat bulky system although nominally mobile.



Right: Very similar in appearance to the Royal Air Force's Bloodhound, Thunderbird was also bought in small numbers by Saudi Arabia and was ordered by Libya (although the order was cancelled by Colonel Gaddafi following his coup d'etat in 1969).

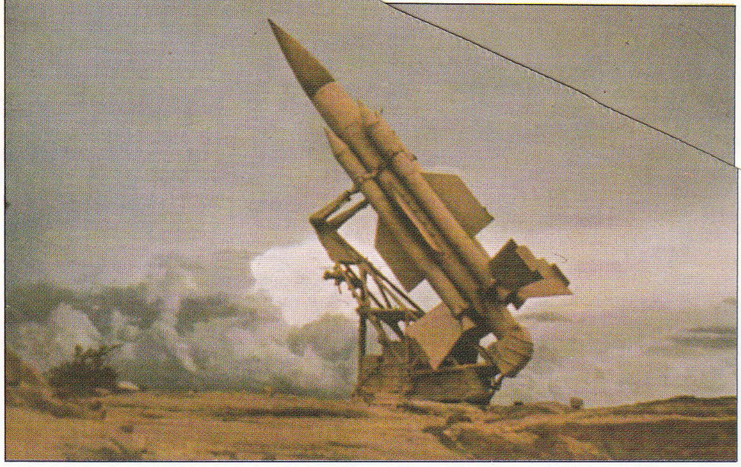
In 1959 the British army's first surface-to-air missile regiment became operational. It was equipped with a bulky but mobile SAM system designated **Thunderbird Mk 1** which had begun life 10 years earlier when English Electric Aviation received the prime contract to develop a SAM system. Curiously, the missile was designed without any reference to earlier British work, specifically the Brakemine missile which had been developed on a shoestring budget from 1943 and might well have evolved into a usable weapon but for indequate funding and the fragmentation of the design team after the end of World War II.

The Thunderbird Mk 1 had fixed cruciform wings with the leading edges swept back at 45°, and pivoted inversely-tapered cruciform tail surfaces indexed in line with the wings. The first test vehicles had a Napier liquid-propellant sustainer, but this was superseded by an IMI solid-propellant motor with consequent advantages in storage, handling, and reliability. Four Bristol-Aerojet wrap-around boost motors were fitted to generate the very high thrust necessary to accelerate the missile at a high angle of elevation into the control of the guidance radar for the semi-active radar homing. An operational battery comprised up to half-a-dozen firing troops each with three launchers and one BTH Stingray target-illuminating radar. The battery command included the Tactical Control Radar and Height-finding Radar.

From 1956 work began on an improved model, the **Thunderbird Mk 2**, which entered service in 1963. Fitted with a higher impulse boost and sustainer motors, it represented a considerable improvement over its predecessor. Its Ferranti Firelight X-band continuous-wave Doppler target-illuminating radar enable it to home in on targets flying at low altitude and could withstand interference from electronic countermeasures. The system had an added advantage in being air-portable in Armstrong Whitworth Argosy aircraft.

The Thunderbird Mk 2 had a service life of some 13 years, serving in the British Army of the Rhine with the 36th Heavy Regiment, Royal Artillery, until 1976. The system did not attract extensive export orders: in 1966 Saudi Arabia invested in a number of Thunderbird Mk 1 systems including some ex-British army weapons which were eventually replaced by HAWK SAMs, and an order for Thunderbird Mk 2s from the kingdom of Libya was cancelled by Colonel Gaddafi after his coup d'etat.

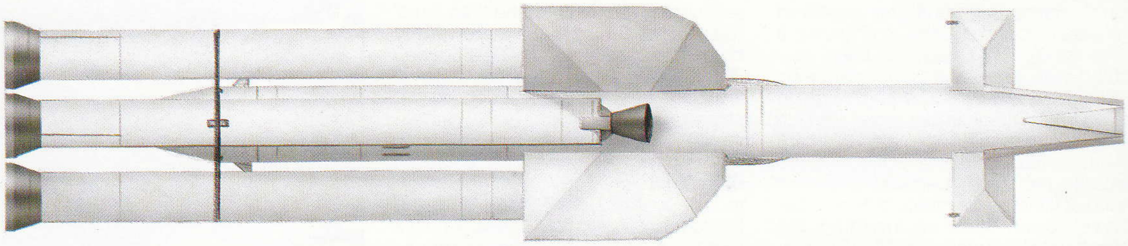
Specification
Thunderbird
Type: long-range land-based SAM
Dimensions: length 6.35 m (20 ft 10 in); diameter 527 mm (20.75 in); span 1.63 m (5 ft 4 in)
Range: 75 km (46.75 miles)
Launch weight: classified
Warhead: continuous-rod HE with proximity fuse



Although a large system, Thunderbird was air-portable in the Armstrong-Whitworth Argosies of the Royal Air Force. It remained in service until the mid-1970s, when it was replaced by the much shorter-ranged Rapier system.

UK

British Aerospace Dynamics Seaslug



Fitted to HMS Devonshire *in 1962, Seaslug was the first effective guided SAM to be adopted by the Royal Navy and finally went to war, 20 years later at the end of its service life, aboard HMS* Glamorgan *and HMS* Antrim *in the Falklands.*

Although the Royal Navy had used unguided anti-aircraft rockets in the early years of World War II, preliminary investigation into the production of guided missiles remained just studies. It was not until 1962, with the commissioning of HMS *Devonshire*, the first of the 'County' class guided-missile destroyers, that the UK went to sea with an effective missile system.

The **Seaslug**, result of a rather protracted development programme lasting from 1949 to 1962, is a large missile designed to counter the classic 1950s threat of high-flying bombers travelling at Mach 0.8. Fired from a twin launcher, the missile comprises a cylindrical body with mid-set rectangular cruciform wings, tail-mounted rectangular cruciform control surfaces and an ICI solid-fuel rocket sustainer, aided by four blunt-nosed solid-propellant boosters wrapped around the nose.

The Seaslug is a beam-riding missile, targets first being detected by long-range Type 965 surveillance radar and Type 277 height-finding radar. Target co-ordinates are fed into the Type 901 missile tracking and illuminating radar, which launches the missile when the target is in range, gathers it into the centre of the pencil radar beam, and passes coded guidance instructions along the beam. The 135-kg (297-lb) warhead has both DA (direct action, or impact) and proximity fuses, and the missile has a secondary surface-to-surface capacity.

The **Seaslug Mk 2** was announced in 1961, but once again development was slow. Nevertheless, though few external changes were made the update considerably enhanced performance in terms of greater speed, range, resistance to ECM and guidance accuracy. Upgraded electronics gave the Seaslug Mk 2 better capabilities against low-flying and surface targets than its predecessor. The new missile was fitted to the second group of four 'County' class destroyers, plans to retrofit the first four coming to nothing.

The Seaslug went to war for the first time 20 years after its service introduction, the Mk 2-armed destroyers HMS *Glamorgan* and HMS *Antrim* playing an important part in the South Atlantic campaign of 1982, although more modern missiles obviously achieved more against the Argentine air force's low-level attacks.

The only systems remaining opertional are the Mk 2s aboard HMS *Fife* and *Glamorgan*, and the Chilean *Prat* (ex-HMS *Norfolk*) and *Almirante Cochrane* (ex-*Antrim*). The Pakistani navy's *Babur* (ex-*London*) was fitted with Seaslug Mk 1, but plans to remove or replace the system are thought to be in hand.

Specification
Seaslug
Type: medium/long-range area-defence ship-borne SAM
Dimensions: length (Mk 1) 5.99 m (19 ft 8 in) or (Mk 2) 6.10 m (20 ft 0 in); diameter 409 mm (16.1 in); span 1.45 m (4 ft 9 in)
Launch weight: not disclosed
Performance: range (Mk 1) 45 km (28 miles) or (Mk 2) 58 km (36 miles); maximum altitude at least 15240 m (50,000 ft)
Warhead: 135-kg (297-lb) HE with impact and proximity fuses

Seaslug saw action for the first time in the Falklands, being used by HMS Glamorgan *and (seen here during the campaign) HMS* Antrim. *Although much improved at low level, the essentially 1950s missile could not measure up to the low-level target of the 1980s.*

USSR

SA-1 'Guild'

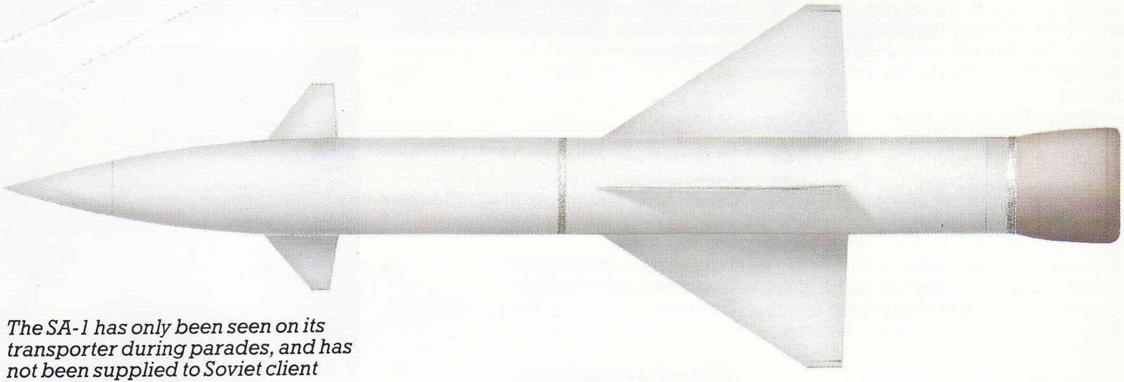
Unaccountably ignored in the West since it first appeared in public, the Soviet missile called **SA-1** by the Pentagon and given the NATO reporting name **'Guild'** should be considered a monumental achievement of weapons development. Although not seen until the Red Square October Revolution parade in November 1960, it has been estimated that the SA-1 entered operational service in 1954, just after the privately developed RSC series developed in Switzerland and contemporary with the American Nike Ajax system. Given the apparent sophistication of the detection and guidance systems associated with 'Guild', development must have started almost immediately after the end of World War II. The tapered cylindrical missile had cruciform cropped delta fins with elevons, and all-moving cruciform cropped delta foreplanes.

In spite of being an extremely large piece of equipment, with room for plenty of propellant (thought to be liquid, although when it first appeared Western sources were convinced it was solid), the 'Guild' has been credited with quite poor performance by Western standards. It is not thought to have a separate boost motor (which would account for the low Western performance estimates) although the missile has never been seen on any kind of launching system; indeed it has never been seen on anything but transporters towed by ZIL-151 tractors.

More recent photographs of SA-1 during Moscow parades of the 1970s have shown the missile with what appears to be a nose radar, possibly the receiver for semi-active radar homing guidance, although there is space enough for an active system. If so, it would make the missile autonomous in the final phase of its approach to the target.

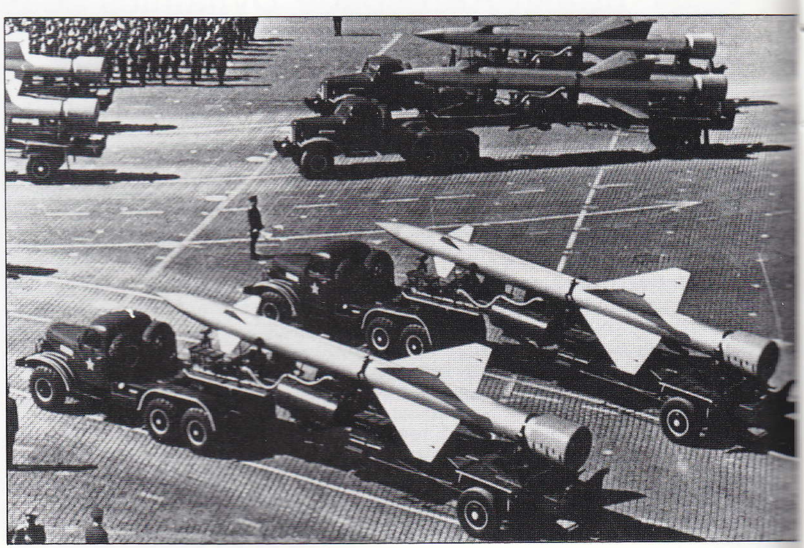
The main ground based radar was given the NATO reporting name 'Yo-Yo', and was of extreme complexity for its time. It has six rotating antennae covering arcs of 70° in both azimuth and elevation. By use of flapping beam techniques (as used on the 'Fan Song' radar of the SA-1's much more widely known successor, the SA-2 'Guideline') 'Yo-Yo' was reportedly capable of tracking up to 30 targets at once, and has a peak power of at least 2 megawatts. When one realizes that this approaches the power of the West's Ballistic Missile Early Warning System radars, it is understandable that the Pentagon classed the 'Guild' and its radar as a strategic defence system.

From a peak in the early 1960s of many hundreds of batteries, the number of 'Guilds' in service has declined until it is now thought no longer to be in service, although some may remain in reserve. The SA-1 was never exported.



The SA-1 has only been seen on its transporter during parades, and has not been supplied to Soviet client states. Western performance estimates are lower than contemporary NATO systems, possibly because 'Guild' does not appear to have a booster motor.

Specification
SA-1 'Guild'
Type: medium-range land-based SAM
Dimensions: length 12.0 m (39 ft 4.4 in); diameter 700 mm (27.56 in); span 2.8 m (9 ft 2.2 in)
Launch weight: 3200 kg (7,055 lb)
Performance: range 32 km (20 miles) according to a British MoD estimate in 1976; maximum altitude not known
Warhead: HE



Seen during the May Day parade of 1968, the SA-1 'Guild' was the first major surface-to-air weapon system built by the Soviets to become known in the West. It was a technological tour de force, especially in the power and complexity of its radar guidance system.

USSR

SA-2 'Guideline'

Unlike the SA-1, the **SA-2 'Guideline'** seems to have been designed from the outset as a mobile system, although as such it is very bulky and the complete system weighs over 100 tons. It first entered service in about 1956, and since that time has been used in combat more than any other SAM, and has seen continuous updating and improvement.

Like many other systems of the 1950s, 'Guideline' appears to have been designed to counter fast high-flying aircraft. Just how high flying was not known, until in 1960 an American Lockheed U-2 reconnaissance aircraft piloted by Francis Gary Powers was brought down from what the CIA, which operated the aircraft, had thought was a safe height. The shocking fact that the missile was capable of shooting down aircraft at the highest altitude forced drastic evolution upon the development of air tactics.

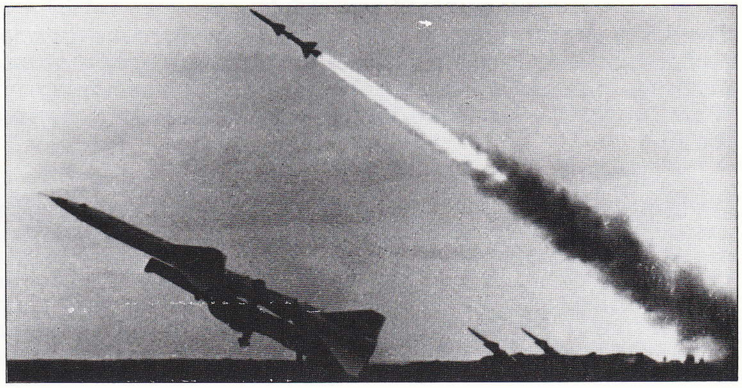
Originally the missile was a shapely design with cruciform rectangular nose surfaces, much larger cropped delta wings towards the tail and small powered control fins mounted at the rear; all these surfaces were indexed in line. The nitric acid/kerosene-powered missile was boosted by a tandem-mounted solid-propellant first stage, which was itself fitted with large delta wings. Later models featured delta nose surfaces, and a model first seen in 1967 had a large white-painted nosecone thought to cover a nuclear warhead in place of the original HE type.

The 'Guideline' is radio command-guided. Each SA-2 battery of six single launchers is linked to a 'Spoon Rest' early warning radar and the regimental level 'Side Net' height-finding radar. These systems acquire and identify targets, and transmit the information to the battery's own 'Fan Song' radar, usually by radio or landline. 'Fan Song' is capable of tracking up to six targets at a time, and in all versions can track-while-scan (tracking targets and passing data to the fire-control computer while simultaneously scanning and trying to acquire new targets). Once launched, the SA-2 is powered by its solid-fuel booster away from the battery, where the liquid-fuel sustainer cuts in. Control signals are transmitted along a narrow line-of-sight UHF radio beam, which must be picked up by the missile within six seconds or it will go ballistic and lose any chance of hitting the target.

The SA-2 eventually shot down six U-2s (one each over the USSR and Cuba, and four over China). The type first saw major combat use in 1965, being fired by India in the war against Pakistan, reducing the efficiency of Pakistani air attacks although only one aircraft was damaged by an SA-2. In the same year North Vietnam launched the first of more than 9,000 missiles against the might of the USA. Initially fairly accurate, the SA-2 was gradually reduced in effectiveness by US countermeasures. The weapon nevertheless remained a threat, although in December 1972, when faced with the kind of target it had been designed to destroy (when the Boeing B-52s bombing Hanoi during 'Linebacker II' were ordered to fly straight bomb runs) the SA-2 achieved only about 2 per cent success.

The other major war zone which has seen extensive use of SA-2s is the Middle East, where the Egyptians were even less successful than the North Vietnamese. This may have been due to the fact that the Israel deployed smaller, faster low-flying aircraft, which are not what the 'Guideline' was designed to engage. It was during the 1967 war, when Israeli ground forces captured a number of SA-2 sites, that it was learned that the Soviet designation for the system was **V75SM**, the missile itself (in the captured version) being known as the **V750 VK**. Incidentally, the ease with which the Israelis evaded the SA-2s fired at them during the 'Six Day War' and the 'War of Attrition' led to a sense of false security about Soviet SAMs before the 'Yom Kippur War', when the much more advanced SA-6 proved a nasty shock.

Combat experience during the SA-2's long lifetime has seen modifications to the fusing guidance and warhead, the addition of radar (those used in the 'Yom Kippur' War of 1973 were reported to have been fitted with terminal guidance), and, above all, enhancement of ECCM. The SA-2 remains in service in diminishing numbers with the USSR, and has been supplied to most Soviet client states as well as to China, Albania and Egypt.



An SA-2 (V 750 as it is known to the Soviets) of the PVO (Air Defence of the Homeland) is launched during an exercise during the early 1960s. It was an SA-2 which ended the era of the high-flying bomber when the Lockheed U-2 spyplane flown by Gary Powers was shot down in 1960.

Specification

SA-2 'Guideline'

Type: medium/long-range land-based semi-mobile SAM

Dimensions: length 10.80 m (35 ft 5.2 in) but varying in some subtypes; diameter (missile) 500 mm (19.69 in) and (booster) 660 mm (25.98 in); span (missile) 1.70 m (5 ft 6.9 in) and (booster) 2.20 m (7 ft 2.6 in)

Launch weight: 2300 kg (5,071 lb)

Performance: operating range 35-50 km (21.75-31.1 miles) according to subtype; maximum speed at burn-out Mach 3-3.5; operating altitude limits 1500 m (4,920 ft) in later models to 28000 m (91,865 ft)

Warhead: 130-kg (286-lb) HE with proximity (and/or radio command or impact) fuse

Certainly the surface-to-air missile to have seen most action, the SA-2 'Guideline' has been in Soviet service since the late 1950s. It is nominally a mobile system, although compared to modern types that mobility is distinctly ponderous.

German Wonder Weapons

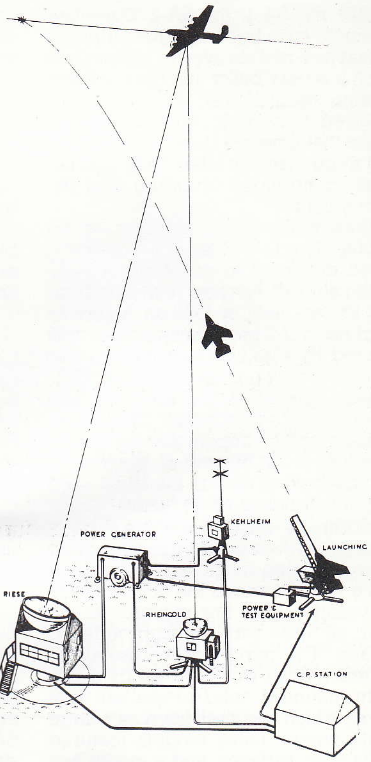
Twentieth-century warfare has proved a fertile ground for scientific and technological development – the need to survive providing an even greater incentive than profit – with the greatest evolution occurring during the two World Wars. World War II saw the genesis of many of the systems which dominate warfare today.

When in the early months of World War II, a speech given by Adolf Hitler threatened his enemies with 'new and secret weapons' then being developed, to the Allied man in the street it seemed another flight of the German dictator's fancy. The professionals took the threat more seriously, and by 1943 such targets as the Wehrmacht Research Establishment at Peenemünde became the subject of massive bombing attack. The introduction of large numbers of jet aircraft to the skies over Europe and the appearance of the V-1 and V-2 (Vergeltungswaffen, or vengeance weapons) it became clear to everyone that for once Hitler had spoken the truth. Even so, it was not until after the end of the war, when Allied scientific investigation teams unearthed details of myriad secret projects, that the staggering variety and scope of German weapons research became apparent. From small arms and guided anti-tank missiles through underwater warfare to guided anti-aircraft, ballistic and inter-continental missiles, German scientists and engineers had probed the limits of available technology and in most instances pushed far forward.

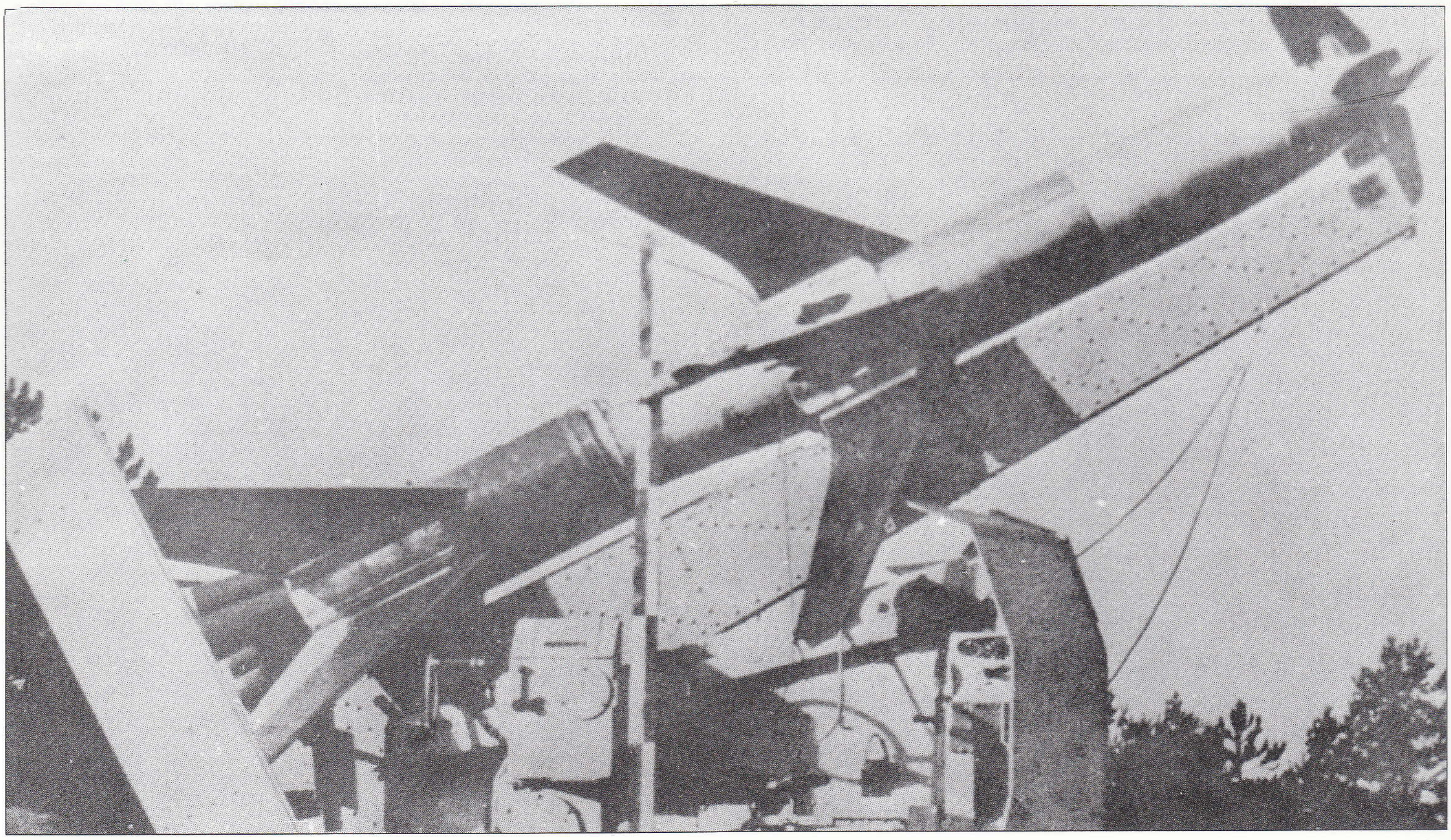
The initial impetus behind the development of German rocketry was the Treaty of Versailles, which ended World War I. German industry was not allowed to manufacture heavy artillery, so the Reichswehr looked to the long-range bombardment rocket (which had not even been conceived in World War I and was thus not covered by the 1919 treaty) as a means of getting around the ban. It was not easy, as large-scale rocketry was in its infancy, and by the time it had become practicable the treaty had long been put aside (although not forgotten in Germany). Nevertheless the pioneering work had been done, and far in advance of that in any other country.

It was fortunate for the Allies that the very real achievements of German science and engineering were not matched by German industry. Indeed, it is the very number of projects being worked on in the last years of the war that point to the reasons for Germany's failure to capitalize on its research led in so many fields. In the completely war-oriented economies of the UK and USA, there was usually some kind of central authority keeping a watchful eye upon weapons development in diverse fields. It was often quickly noticed when designers or factories were working along parallel lines, or had come up with genuinely new ideas. In the first case resources would be pooled, or a less promising line of research aborted with minimum waste of time and money. In the second case, if a real need for the weapon was clear the manufacturer could be allocated test facilities and be given access to specialist advice (which often took the form of the men who would use the equipment in battle).

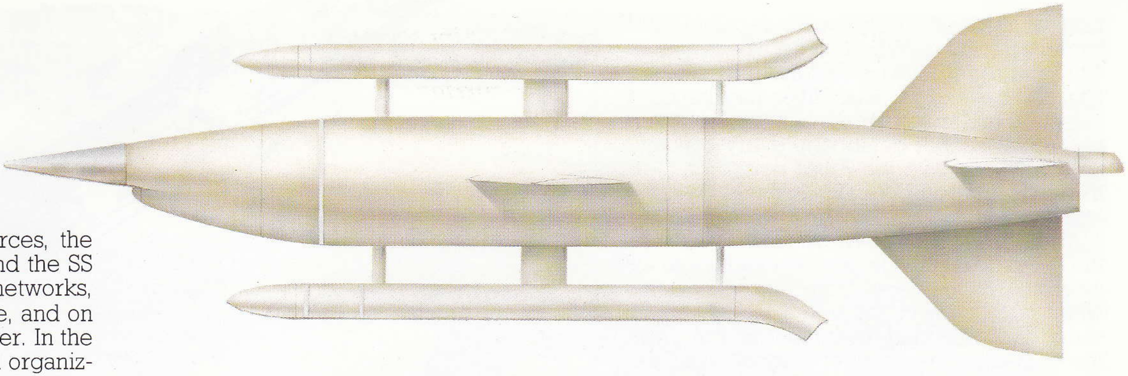
By contrast, the German approach reflected the multiple structure of the Nazi state, with entirely separate party and national adminis-



The Elsass radio command system used a Mannheim radar for target tracking, a Rheingold radar for missile tracking, and a Kehlheim radio link for command transmission.



Rheintochter 1 on its launcher displays many of the features common to today's missiles, with cruciform wings and nose-mounted control surfaces. The two-stage missile used solid propellant.



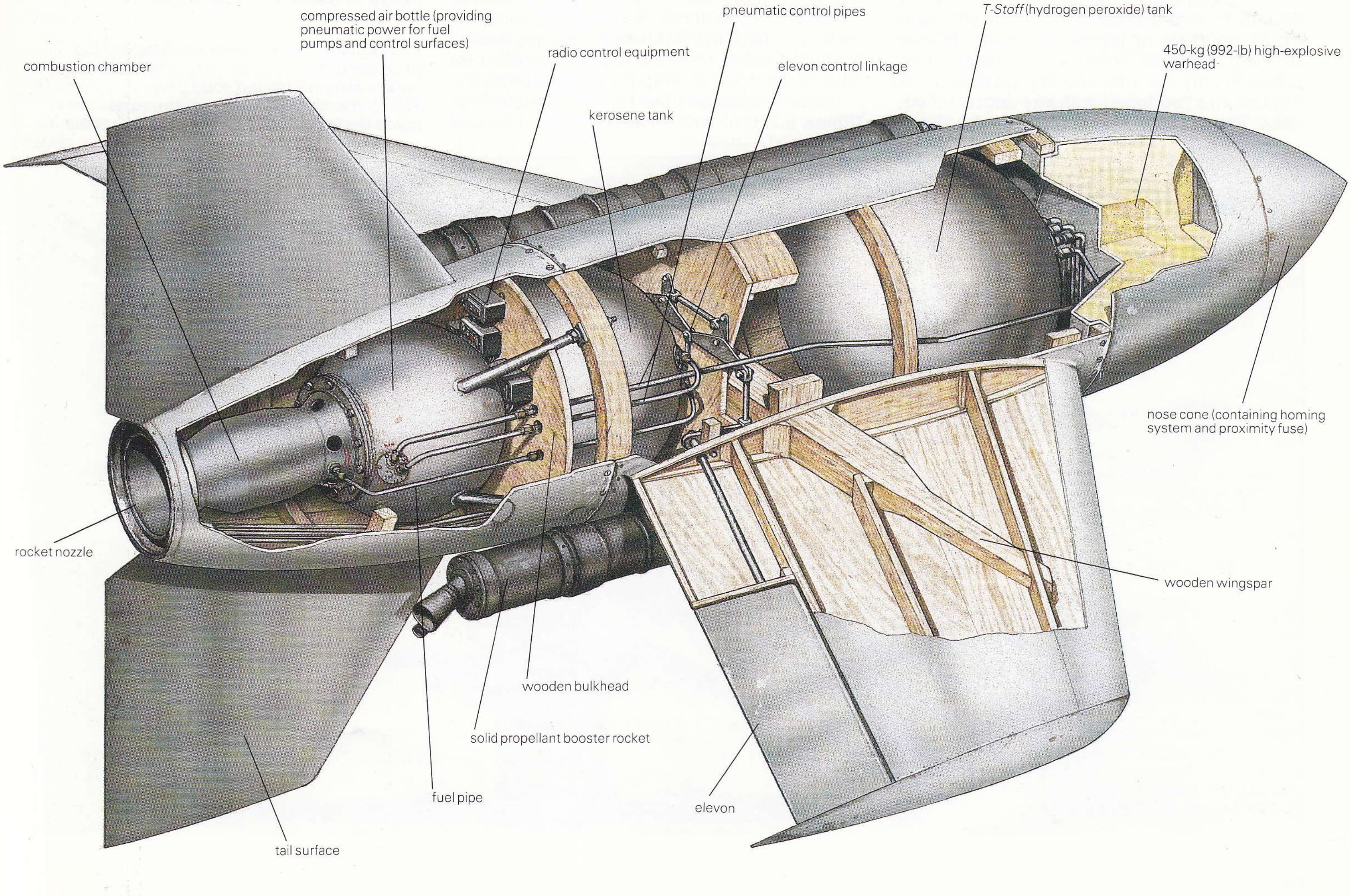
Henschel's Hs 117 Schmetterling *(butterfly) is seen in launch configuration with a pair of strap-on solid-propellant booster rockets being fitted to the winged missile. The pointed nose was intended to house a Fox radio proximity fuse.*

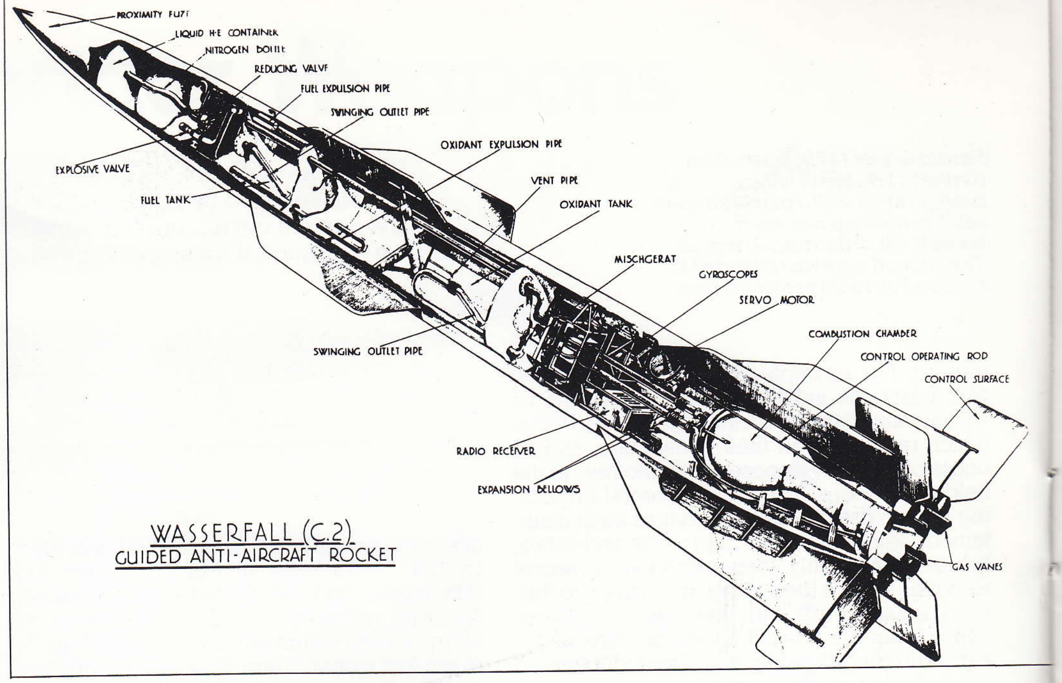
trations. For example, the armed forces, the Nazi party, the individual services and the SS all maintained their own intelligence networks, which rarely shared their knowledge, and on occasion actively opposed one another. In the field of weapons research no central organizing body existed, and the services each maintained their own research projects and establishments. Naturally, these were kept as secret as possible from their rivals. In addition to this, the manufacturers had their own pet ideas, which often occupied the valuable time of design and engineering staff, and duplicated efforts being made elsewhere. On top of all these handicaps, the allocation of factory space and raw material depended upon catching the attention of as high-ranking a party official as possible. If the idea took the fancy of the Führer himself then the most outlandish of schemes had a chance to propser.

Organizational chaos was not the only factor affecting the misdirection of the Nazi war effort. In 1941, with most of Europe under Axis domination, and the German army's Panzers spearing into the heart of European Russia, the German high command made a conscious decision that research and development of defensive weaponry 'was unnecessary as the war was going so well. Anything which was not likely to be in production within a year was to be cancelled. Many promising programmes suffered, but none more than these concerned with air defence of the Reich. Irreplaceable research teams were broken up, with highly-qualified scientists and engineers being conscripted into the services.

It was not until 1943, with regular British, 1,000-bomber night raids and the ever increasing force of USAAF day bombers appearing over Germany, that the nature of the threat became obvious to a Nazi leadership rapidly losing any grasp of reality it may once have possessed. The revelation that the UK had far more advanced radar equipment than Germany (revealed when an Avro Lancaster equipped with H_2S blind-bombing radar crashed near Rotterdam) led to Hitler calling a conference which was instructed to close the gap. Commissions were set up, surviving mem-

ENZIAN Surface-to-Air Missile


compressed air bottle (providing pneumatic power for fuel pumps and control surfaces)
pneumatic control pipes
T-Stoff (hydrogen peroxide) tank
radio control equipment
combustion chamber
elevon control linkage
450-kg (992-lb) high-explosive warhead
kerosene tank
nose cone (containing homing system and proximity fuse)
rocket nozzle
wooden wingspar
wooden bulkhead
solid propellant booster rocket
fuel pipe
elevon
tail surface


PROXIMITY FUZE
LIQUID H·E CONTAINER
NITROGEN BOTTLE
REDUCING VALVE
FUEL EXPULSION PIPE
SWINGING OUTLET PIPE
OXIDANT EXPULSION PIPE
EXPLOSIVE VALVE
VENT PIPE
FUEL TANK
OXIDANT TANK
MISCHGERAT
GYROSCOPES
SERVO MOTOR
SWINGING OUTLET PIPE
COMBUSTION CHAMBER
CONTROL OPERATING ROD
CONTROL SURFACE
RADIO RECEIVER
EXPANSION BELLOWS
WASSERFALL (C.2)
GUIDED ANTI-AIRCRAFT ROCKET
GAS VANES

Wasserfall *was by far the most ambitious of the German surface-to-air missile programmes, with a designed performance which would have been effective even in 1960.*

bers of research teams were recalled, and funding was found. What could not be regained were the two lost years, and this was to prove fatal. By the end of 1944, Hitler had issued a directive seeking to 'strengthen the firepower of the anti-aircraft defence in every conceivable way', but with the Allies poised on Germany's Eastern and Western borders it was too little too late.

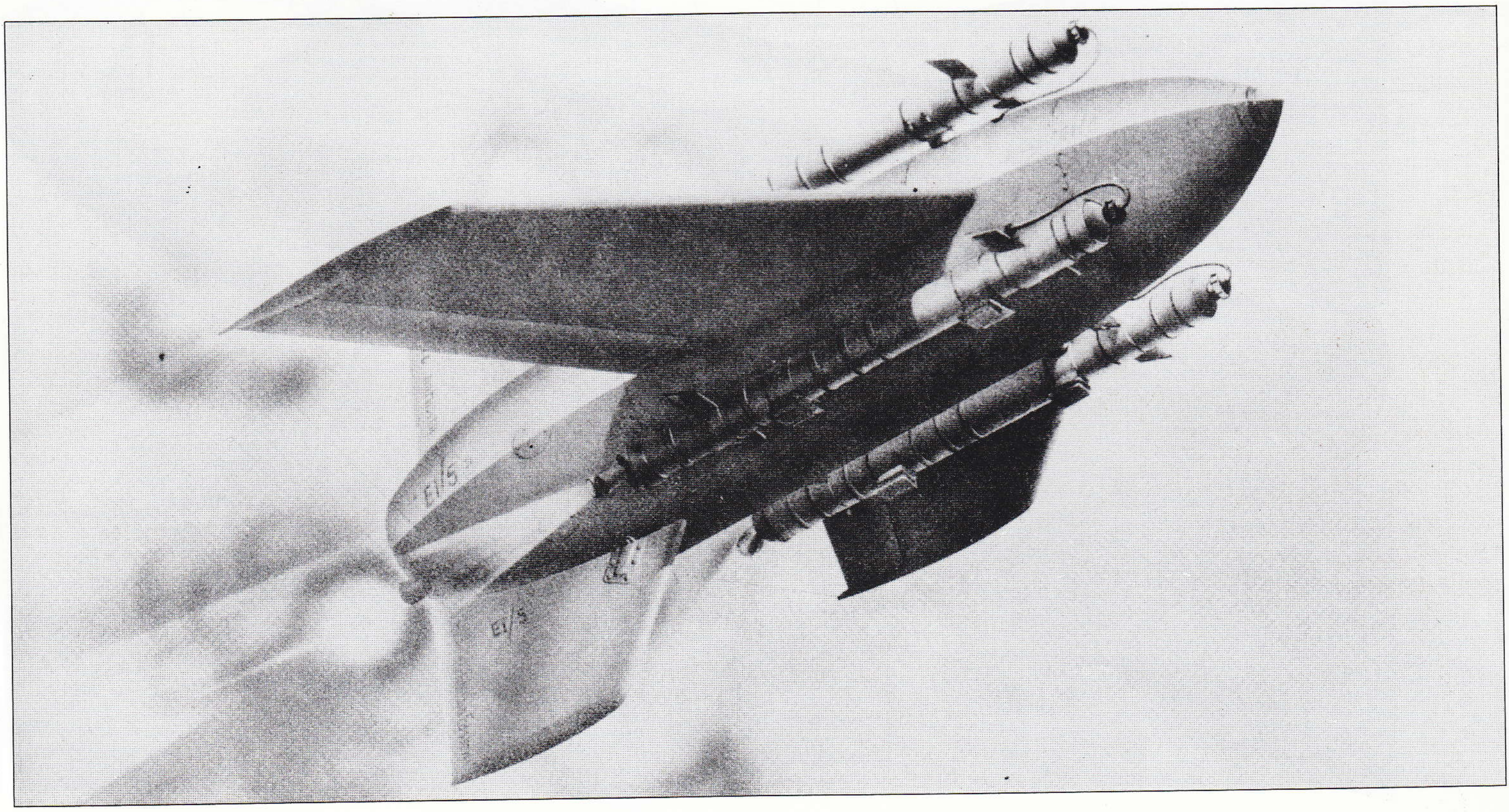
It was this 1944 directive which was to prove the foundation of much post-war surface-to-air missile development. Many of the systems which appeared in the last year of the war seem crude by modern standards, but given the contemporary level of technological development they represented almost as great a leap as the development of the aeroplane itself. Among the designs (many of which existed solely on paper) were solid- and liquid-fuelled subsonic and supersonic guided missiles; submarine-, ship- and man-portable systems; unguided barrage rockets; radio and radar command guidance; television, active radar, semi-active radar, passive radar and infra-red homing systems; and a bewildering array of acoustic, infra-red, television and electro-magnetic proximity fuses.

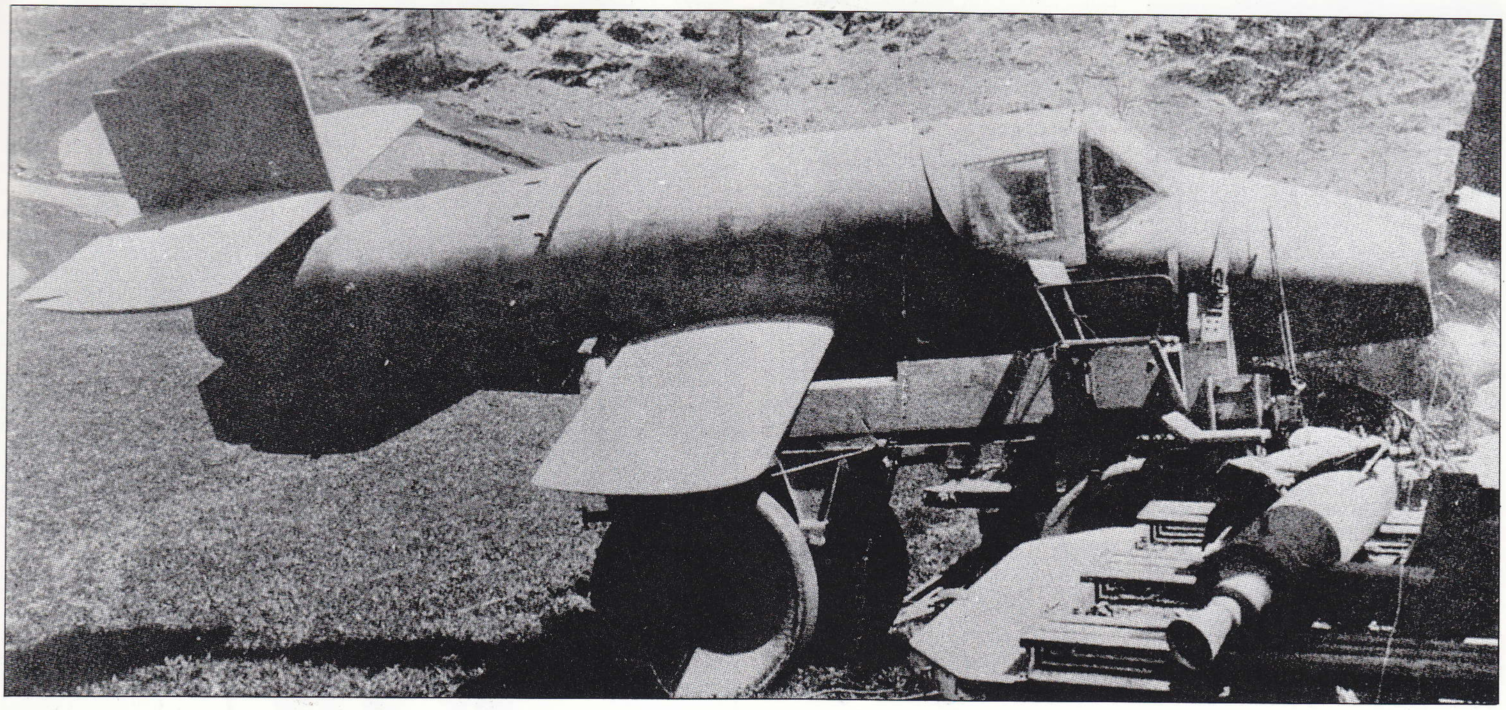
Most of the missiles for which these new guidance systems were developed were winged subsonic or trans-sonic types. Enzian (gentian), designed by Dr Wurster of Messerschmitt AG, started life with the Luftwaffe designation FR (Flak Rakete) 1, and was exceptionally powerful. Winged, and powered by a bi-propellant liquid fuelled sustainer, Enzian was assisted on take-off by four wrap-around solid-fuelled boosters. Guidance was initially by radio command, the operator tracking the missile to within homing range of the target either optically or by radar. Three different homing systems were to be developed, although only the infra-red system designated Madrid was produced with any degree of success. The acoustic system remained a design on paper, and the semi-active radar homer had an alarming tendency to lock onto the illuminating radar rather than the target. Several different proximity fuses were considered for the 450-kg (992-lb) warhead which Enzian was to carry to Mach 0.66 and an altitude of 15850 m (52,000 ft). A supersonic version was being considered at the war's end.

The Henschel Hs 117 Schmetterling (butterfly) was smaller, with a 25-kg (55-lb) warload. No homing system was carried, guidance being by radio control all the way to the target. The Fox radio proximity fuse (also intended for Enzian) would have been carried had the missile been more successful in trials. Effective range was to be about 16 km (10 miles) with a ceiling of 10670 m (35,000 ft). Propulsion was by a liquid-fuelled rocket sustainer, boosted on take-off by a pair of strap on solid-fuel rockets.

Unlike Enzian and the Hs 117, Rheintochter (Rhine maiden) was a two-stage solid-fuelled missile. Guidance once again was by radio command, optical tracking being aided by flares attached to the missile. The specification called for a high subsonic speed, and a ceiling of 6000 m (19,685 ft). The 150-kg (331-lb) warhead was fitted with the Kranich acoustic proximity fuse (probably the best of all such systems developed in Germany, with a response range of approximately 7 m/23 ft).

The engineers at Messerschmitt solved the problem of boosting the very large Enzian by means of wrap-around solid propellant rockets. The alternative, a tandem rocket, would have made the system very unwieldy on the ground.



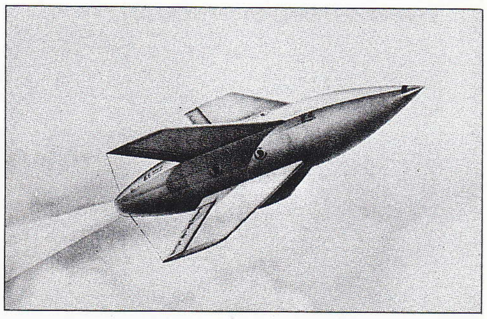


One of the more interesting German surface-to-air missiles was the Bachem Natter (adder)*, which replaced the complex guidance systems of other missiles with a pilot, who baled out after attacking enemy aircraft with a battery of 73-mm rockets in the nose. This example was captured in Bavaria.*

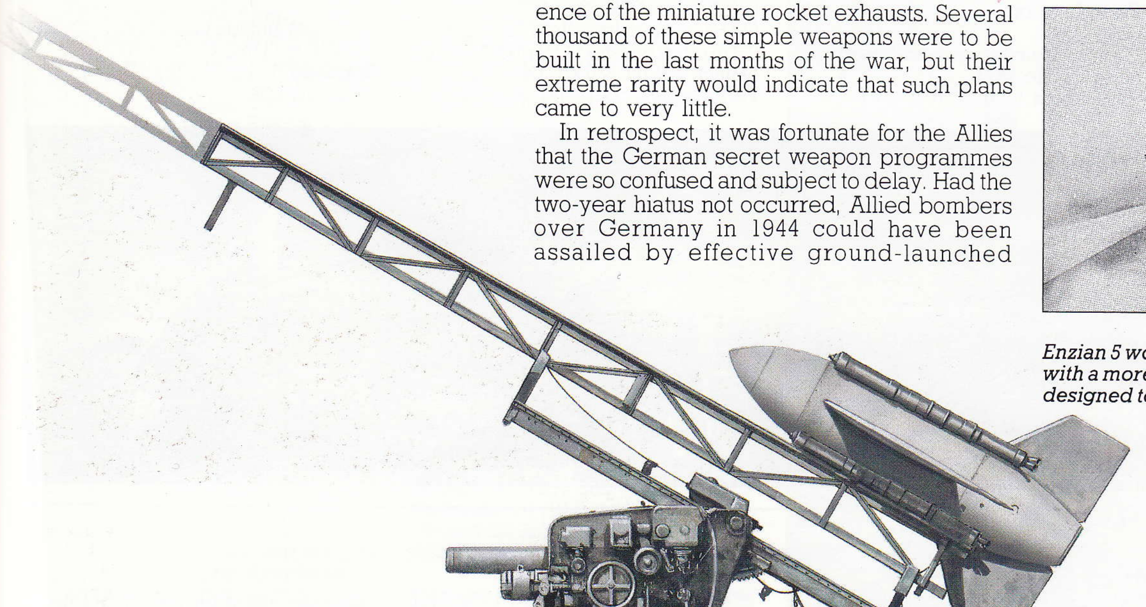
Wasserfall (waterfall) was a much more ambitious weapon, conceived to counter targets flying at 885 km/h (550 mph) at heights of up to 19800 m (65,000 ft). Developed at Peenemünde, Wasserfall resembled a scaled down A-4 (V-2) rocket and used much of the technology developed for that weapon. The missile was supposed to be supersonic, although it did not achieve the speed of sound in early trials, and so probably did not reach the designed range of 48 km (30 miles). It was radio command guided, and was to have been proximity fused, although which of the many such fuses being developed was never decided.

Many other projects reached the development stage, including free-flying barrage types such as Taifun (30 liquid-fuelled 10-cm/3.94-in diameter rockets per projector) and Fohn (35 spin-stabilized 7.3-cm/2.87-in diameter missiles per launcher) both of which were designed to use modified Flak 88 mounts. By contrast, Flieger Faust (flying fist) was a nine-barrel man-portable rocket-launcher designed for use against low-flying aircraft. Standard 20-mm cannon shells were fitted to small solid-propellant sticks and clip-loaded into the shoulder launcher. When the trigger was pulled, five rockets were fired, followed a tenth of a second later by the other four. The interval was designed to minimize the mutual interference of the miniature rocket exhausts. Several thousand of these simple weapons were to be built in the last months of the war, but their extreme rarity would indicate that such plans came to very little.

In retrospect, it was fortunate for the Allies that the German secret weapon programmes were so confused and subject to delay. Had the two-year hiatus not occurred, Allied bombers over Germany in 1944 could have been assailed by effective ground-launched weapons, and the low-flying fighter-bombers so essential to maintaining air superiority over the battlefields of North West Europe would have faced a questionable future indeed. There can have been few decisions more costly than that by Hitler and his advisers in the summer of 1941.



Enzian 5 would have been a trans-sonic missile, with a more powerful motor and swept wings designed to carry the weapon beyond Mach 1.



In common with a number of missiles, Enzian was launched off a modified Flak 88 gun mount. The system could have been relatively mobile had it ever become operational, although dependence upon large fixed radar systems for guidance may have hampered that mobility.

USSR

SA-3 'Goa'

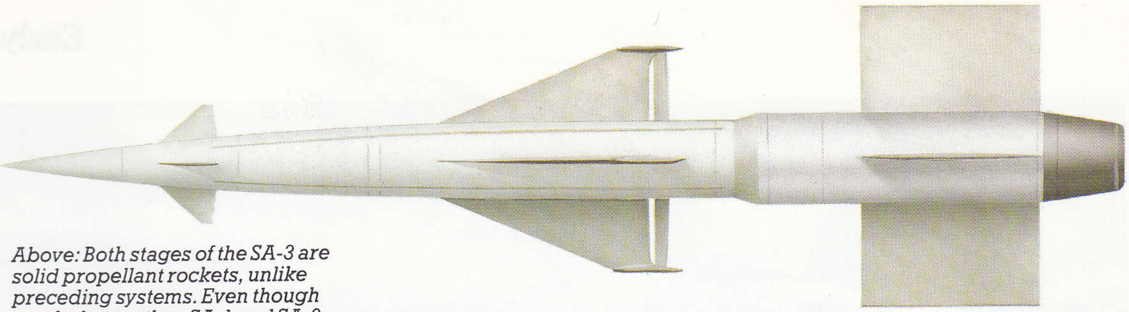
Essentially a medium-altitude partner to the SA-2 'Guideline', the **SA-3 'Goa'** is one of the same generation, being introduced in 1961. Considerably smaller than 'Guideline', the 'Goa' is more manoeuvrable, but in early models used a similar radio command-guidance system, and shared the larger missile's vulnerability to electronic countermeasures. Like the SA-2, the 'Goa' uses a solid-fuel booster, but the second stage sustainer is also of the solid type, unlike the liquid-propellant sustainer of the earlier missile.

SA-3 missiles are normally carried in pairs on their launch rails on the back of the same ZIL-157 tractors used to tow the much larger SA-1 and SA-2 trailers. When used for base defence, the 'Goa' is fired from a power-rotated twin launcher at an elevation of 75°. More recently, the SA-3 has been seen on triple launchers in Yugoslavia, and a quad launcher has been introduced to the air-defence forces of the Warsaw Pact.

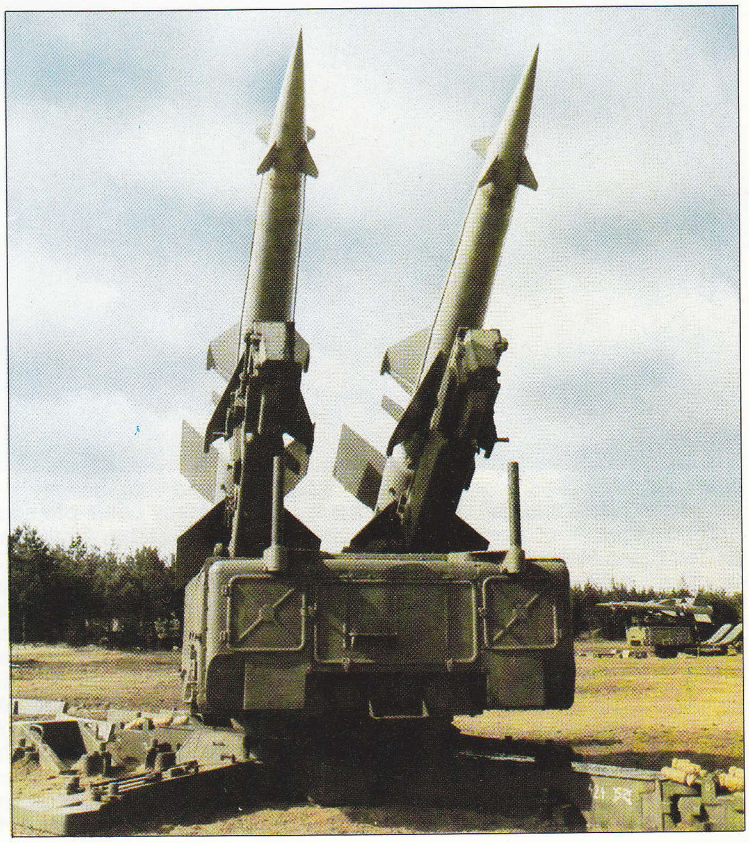
Although technically a mobile system, the SA-3 is somewhat cumbersome in comparison with more recent systems, but the Soviet tendency to retain in service systems that work reasonably well has seen the 'Goa' transferred from the army to the air-defence forces, by whom the type is used for short-range defence of airfields.

The radar systems associated with the 'Goa' include 'Flat Face' early warning and target-acquisition radar, which has a range of some 250 km (155 miles), and the 85-km (53-mile) range 'Low Blow' target-tracking and missile-guidance radar, which can track up to six targets at once and guide up to two missiles to each target. 'Low Blow' is optimized for target detection at low level, and is reported to be able to pick targets out of ground clutter. Later models may have optical tracking equipment fitted to the radar system for use in intensive ECM environments. The missile itself is radio command-guided, but may have been fitted with semi-active radar homing for guidance in the terminal phase of the attack.

The SA-3 first saw action during the 'War of Attrition' in the Middle East, but Israeli countermeasures developed to deal with the SA-2 were found to be effective against the smaller missile. Nevertheless the 'SA-3' was the most numerous Arab SAM of the 1973 'Yom Kippur' war, although it was overshadowed by the much more effective SA-6 'Gainful'. It has been supplied to most Soviet client states, as well as to countries such as Peru, Uganda and India. The 'Goa' has also been taken to sea by the Soviet navy as the **SA-N-1**, and in this form has become one of the principal anti-aircraft defences of the Soviet fleet.



Above: Both stages of the SA-3 are solid propellant rockets, unlike preceding systems. Even though much shorter than SA-1 and SA-2, 'Goa' is still a substantial piece of equipment, weighing in at 636 kg (1,402 lb) and with a length at launch of some 6.7 m (22 ft).



Right: SA-3 'Goa' has been used in both mobile and static versions, the former being less common today as more modern systems enter service. In the airfield defence role, 'Goa' is mounted on a powered twin launcher which can elevate to 75° and which is fixed in place.

Specification

SA-3 'Goa'

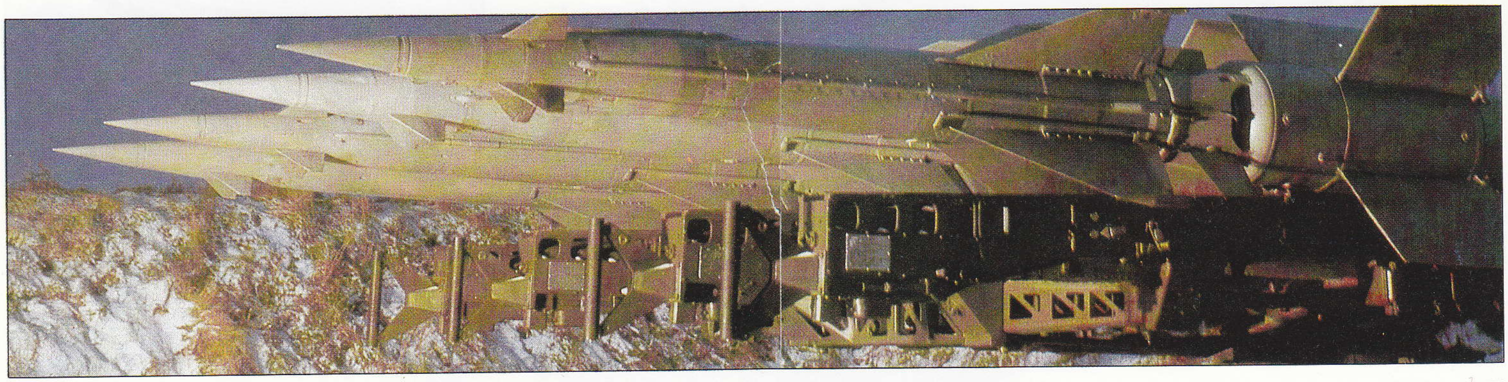
Type: medium-range land-based semi-mobile SAM

Dimensions: length 6.70 m (21 ft 11.8 in); diameter (missile) 450 mm (17.72 in) and (booster) 600 mm (23.62 in); span (missile) 1.22 m (4 ft 0.3 in) and (booster) 1.50 m (4 ft 11.1 in)

Launch weight: 636 kg (1,402 lb)

Performance: operating range 18-30 km (11.2-18.6 miles) according to model; speed at burn-out Mach 3.5; operating altitude limits 1500-13000+ m (4,920-42,650+ ft)

Warhead: 60-kg (132-lb) HE with proximity fuse



More recently, SA-3s have been fitted to quadruple launchers in the various air defences of the nations of the Warsaw Pact. In common with most Soviet systems, 'Goa' has been the subject of continuous updating, to make an essentially crude system suitable for the modern battlefield.

USA

Bomarc

Developed for the US Air Force, the **XF-99 Bomarc** was a pilotless interceptor of aeroplane configuration built to withstand vertical launch and speeds of up to Mach 4. The tips of its wings pivoted to act as ailerons, the pivoted top of the fin served as a rudder, and powered slab tailplanes provided the elevator function. Because the Bomarc was intended for long-range area defence, it was apparent that semi-active homing would be inadequate, so the Bomarc became the first active-homing SAM (carrying its own radar) to be deployed for active service. The Bomarc was not intended as a mobile system, but was assigned to Air Defense Command and initially could be launched from its shelter within 2 minutes of SAGE/BUIC acquiring a target, a time later reduced to about 30 seconds.

The missile was launched without pre-programmed guidance by a tail-mounted 15876-kg (35,000-lb) thrust Aerojet-General LR59-AJ-13 acid/JP-4 rocket motor and after a few moments the two ramjets carried on pylons beneath the body were lit. Burning 80-octane gasoline, the Marquardt RJ43-MA-3 ramjets each developed 4536 kg (10,000 lb) of thrust, and once they had cut in the aerodynamic controls became operative. After reaching some 19812 m (65,000 ft) in an inverted climb, the missile half-rolled and assumed a positive-g trajectory and, when within 16 km (10 miles) of the target, the Westinghouse radar in the Bomarc's nose took control, removing the missile from SAGE control and locking onto the target. The DPN-34 radar then active-homed the missile over its last stage. In October 1957 a Bomarc was launched from Patrick AFB, Florida, under control of the SAGE centre at Kingston, New York, and successfully intercepted an X-10 flying at Mach 1.6 at an altitude of 14630 m (48,000 ft). A year later two Bomarcs were launched and controlled by a SAGE centre 2400 km (1,500 miles) from the firing point and tracked down a brace of target drones 160 km (100 miles) out to sea within seconds of each other, one of the unarmed missiles actually managing to ram its target.

The initial production version, the **Bomarc A** by that time designated **IM-99A** (**CIM-10A** from 1962), entered operational service in December 1960: total production was 366 missiles, and one or two 28-missile squadrons were deployed to defend McGuire, Suffolk County, Otis, Dow and Langley AFBs. However, work had already commenced on an improved version, the **Bomarc B** otherwise known as the **IM-99B** (**CIM-10B** from 1962) which had managed its first test firing in May 1959. The Aerojet-General liquid-propellant booster was replaced in this model by a jettisonable Thiokol M51 solid-propellant model (22680-kg/50,000-lb thrust for 30 seconds), which reduced the reaction time between the missile unit being alerted and Bomarc being fired from 2 minutes to a matter of seconds. Range was substantially increased by extra tankage for the two 6350-kg (14,000-lb) thrust RJ43-MA-7s, enabling a missile to defend an area of approximately 1.3 million km^2 (500,000 sq miles). The IM-99B had a number of teething troubles, but demonstrated its capability in 1961 by intercepting a Regulus 2 supersonic target drone at a height of 30500 m (100,000 ft), 718 km (446 miles) from its launching site. The type's had the world's first production pulse-Doppler radar, the Westinghouse DPN-53.

The Canadian government cancelled its Avro Arrow interceptor in 1959 and elected to purchase the IM-99B for the Royal Canadian Air Force. Initial IM-99B deliveries were made to the USAF in 1961, the first unit (at Kincheloe AFB) becoming operational in June of that year. Some 349 missiles were manufactured by Boeing in 1961-5. The Bomarc was designed to carry a nuclear or HE warhead. The last Bomarc squadrons were decommissioned in 1972.

Specification

IM-99 Bomarc

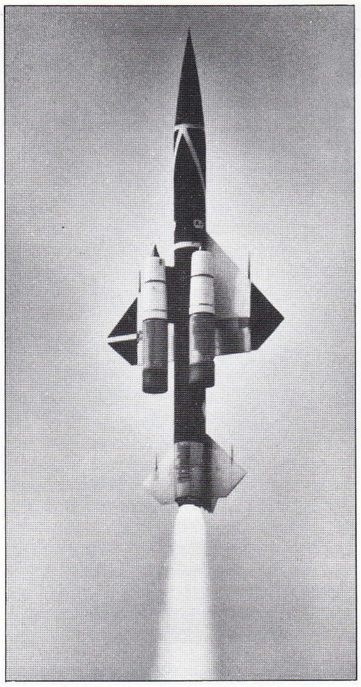
Type: long-range land-based interceptor missile

Dimensions: length (IM-99A) 13.80 m (45 ft 3 in) or (IM-99B) 13.30 m (43 ft 9 in); diameter 890 mm (2 ft 11 in); span 5.54 (18 ft 2 in)

Launch weight: (IM-99A) about 6804 kg (15,000 lb) or (IM-99B) 7258 kg (16,000 lb)

Range: (IM-99A) 370 km (230 miles) or (IM-99B) 709 km (440 miles)

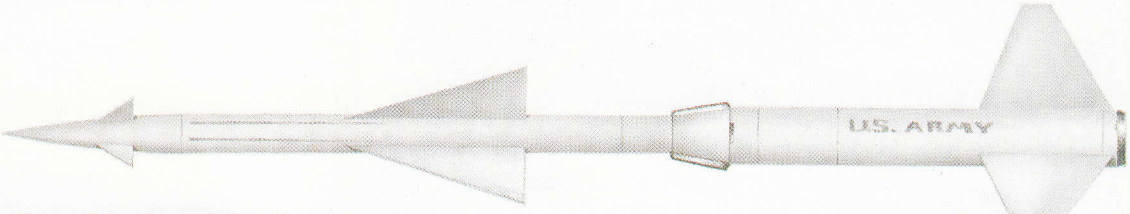
Warhead: nuclear or HE



Bomarc was a very long-range SAM which some people believed could render manned interceptors obsolete. The Canadians cancelled their very promising Avro Arrow fighter in favour of Bomarc.

USA

Nike Ajax



Above: A slender and elegant missile, Ajax was propelled by a solid-fuel, three-finned jettisonable booster and a liquid propellant sustainer. Speed at burnout was Mach 2.3 and it carried a variety of warheads containing shrapnel, optimized for use against aircraft.

Nike was the ancient Greek goddess of victory, and it was an appropriate choice of name for the missile system which became the world's first operational guided SAM. It achieved this status just before Christmas 1953, near Washington DC. Its gargantuan steel and concrete emplacement was a far cry from later mobile systems. The system was rapidly rendered obsolete, but it was nevertheless an impressive technological achievement.

Nike Ajax was designed to protect the continental USA from bomber attack, and no requirement for mobile operational use was envisaged when it was developed as the **SAM-A-7**, later **M1** and **MIM-3**. Although not actually hardened against nuclear attack, the launch sites were constructed with much of their facilities underground. From 1956 the Western Electric (BTL) acquisition radar was linked to the Semi-Automatic Ground Environment (SAGE) network which was supposed to track every intruder and assign it a specific SAM or interceptor aircraft. The acquisition radar passed the target to a target-tracking radar which provided target data for a computer which launched the command-guided missile into the beam of a missile-tracking radar. Maintaining one beam on the missile and one on the target, the computer drove the beams to a coincidence point at a predicted future target position and commanded the missile's warhead to explode when the missile was just below the target's nose.

Nike Ajax was a slender missile, with cruciform delta fins and controlled by four cruciform foreplanes. It was powered by a Bell Aircraft liquid-propellant sustainer developing 1179 kg (2,600 lb) of thrust for 21 seconds, plus a Hercules Powder Company solid-propellant three-finned jettisonable booster providing 26762 kg (59,000 lb) of thrust for 2.5 seconds. The speed at burnout point was Mach 2.3, and three different-sized warheads were provided, each surrounded by 6.35-mm (0.25-in) metal cubes, the optimum size discovered for aerial shrapnel.

Ajax was widely exported, installations being delivered to most major West European armed forces plus Japan, Taiwan and Turkey. In 1958 the US Army had 40 battalions operating the system, each of 36 or 48 launchers. Nearly all these sites were later converted to Nike Hercules. Some 16,000 missile were produced.

Specification

Nike Ajax

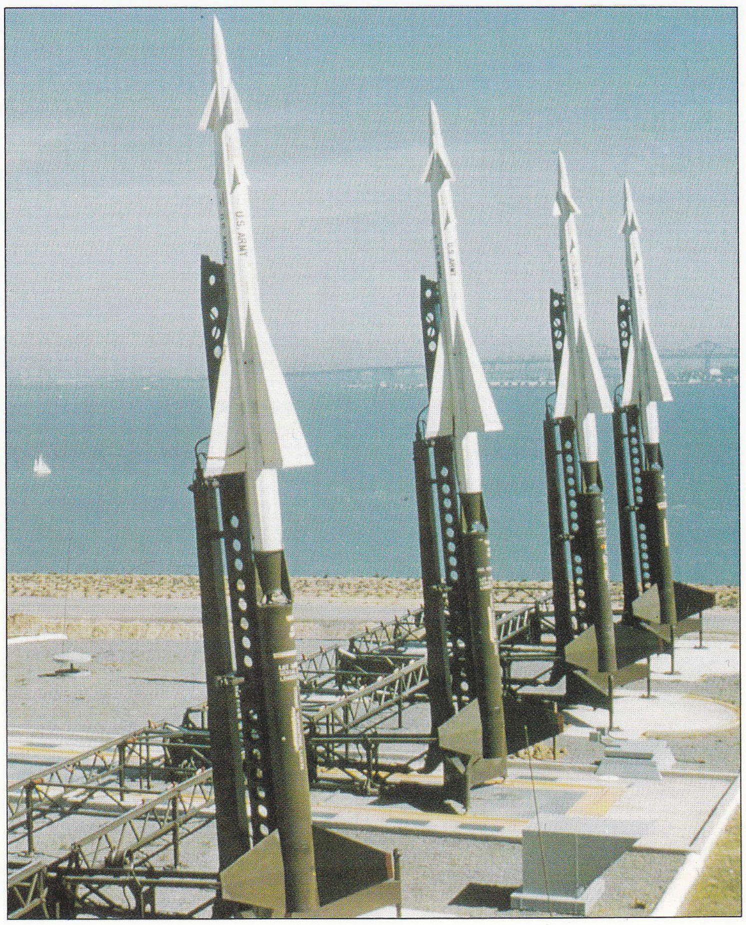
Type: long-range land-based SAM

Dimensions: length 10.62 m (34 ft 10 in); diameter 305 mm (12 in); span 1.22 m (4 ft 0 in)

Launch weight: with booster 1114 kg (22,455 lb)

Range: 40 km (25 miles)

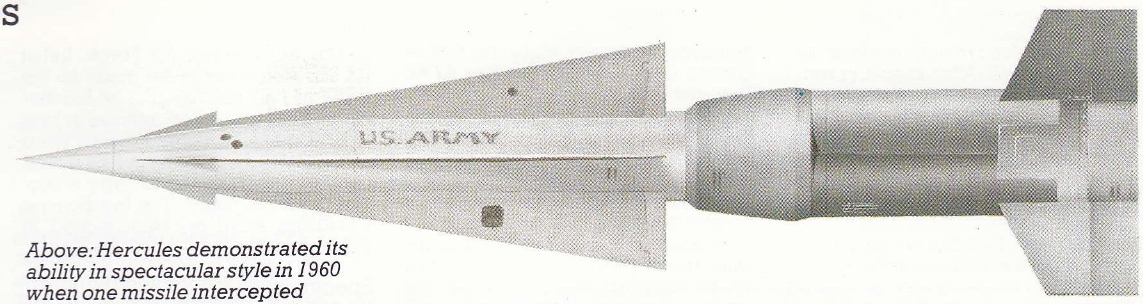
Warheads: 5.4-, 81.2- and 55.3-kg (12-, 179- and 122-lb) HE fragmentation with command detonation



Ajax was the world's first operational SAM, first deployed in a colossal concrete and steel emplacement outside Washington in 1953. Designed purely to defend the continental USA from bomber attack, there was no requirement for the system to be mobile.

USA

Nike Hercules



Above: Hercules demonstrated its ability in spectacular style in 1960 when one missile intercepted another at a closing speed of over Mach 7 at an altitude of 30600 m (100,000 ft). Neither speed nor altitude would save an aircraft from Hercules.

The Nike Ajax programme was on so large a scale that the decision to replace it could not be undertaken lightly, yet as early as 1951 it was recognized that the system would be unwieldy and complex. The **SAM-A-25 Nike Hercules** successor system had thus to be grafted on to the existing one and be compatible with its radar, computers and associated equipment. Western Electric, the prime contractor for Nike Ajax, successfully integrated the much superior Hercules missile with the Ajax's infrastructure, and by the summer of 1958 the Ajax batteries defending New York, Chicago and the capital had been converted to Hercules. The missile was later designated **M6** and then **MIM-14**.

Hercules had dramatically improved performance (derived largely from the use of a Radford Arsenal/Borg-Warner solid-propellant booster, each of whose four tubes had performance equal to the single-tube booster of the Ajax), making it no longer feasible for an aircraft to avoid destruction simply by flying at very high altitude. Able to destroy targets at altitude of 45720 m (150,000 ft) and with a burn-out speed of Mach 3.65 (Mach 3.35 in early missiles), the Hercules at the time of its introduction seemed to place a question mark over the value of manned bombers. Tied in with the General Electric HIPAR (HI-Power Acquisition Radar), Hercules demonstrated its ability in spectacular fashion during 1960 when such a missile launched from the White Sands Missile Range, New Mexico, intercepted another Hercules 48 km (30 miles) from the launch site, 30.6 km (19 miles) above the Earth at a closing speed of Mach 7. Earlier in the same year, a Hercules had successfully destroyed an incoming Corporal ballistic missile. Against low-flying targets the Hercules was considerably less effective, but it did have a complementary surface-to-surface ability. In 1961 experiments were conducted with a Nike Hercules fired from a prototype mobile battlefield transporter/launcher, paving the way for later-generation weapons of far greater tactical mobility.

The missile itself was based on a tapered cylindrical body with saw-toothed low-aspect-ratio delta wings in cruciform configuration along virtually the full length of the body. Control was effected by trailing-edge elevons. Command guidance was used, and the alternative HE or nuclear warheads were command-detonated.

1963 was the high point for the Hercules in the US Army, with 134 batteries in service. The system was exported to Belgium, Denmark, West Germany, Greece, Italy, Japan, the Netherlands, Norway, South Korea, and Turkey. A 48-launcher battalion deployed to Taiwan in 1958 was handed over to the Chinese Nationalist army. In Japan, the non-nuclear version was manufactured under licence by Mitsubishi, which was still building Hercules missiles in the late 1970s despite the complete obsolescence of the system. Total production of Hercules exceeded 25,000. The last Hercules missiles were withdrawn from active service in the USA in 1974, although several batteries were retained for training.

Specification

Nike Hercules

Type: long-range land-based SAM

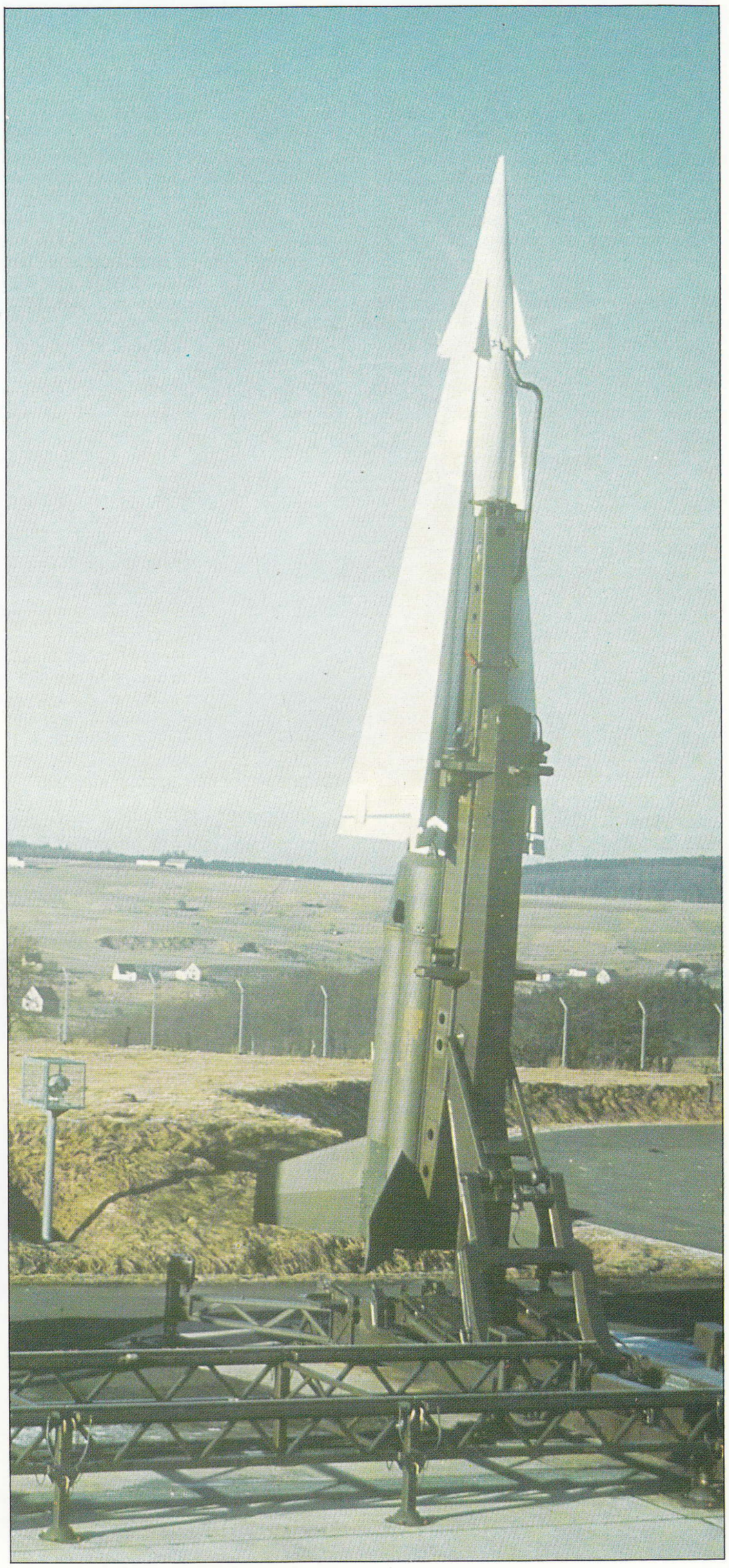
Dimensions: length with booster 12.50 or 12.65 m (41 ft 0 in or 41 ft 6 in); diameter 800 mm (31.5 in); span 1.88 m (6 ft 2 in)

Launch weight: 4845 kg (10,710 lb) or 4,720 kg (10,450 lb)

Range: 140 km (87 miles)

Warhead: nuclear or HE

Below: Ajax was deployed at great expense, but was known to be an unwieldy system even as deployment proceeded. Hercules was a much superior missile designed to be grafted on to the existing Ajax launching sites.



Right: Hercules was deployed on a large scale; the US Army fielded 134 batteries by 1963, and it was adopted by most NATO powers as well as Taiwan and Japan where it was manufactured under licence. This example is operated by the Belgian armed forces.

USA

Nike Zeus

A substantial improvement over Hercules, the **XLIM-49A Nike Zeus** was designed to deal with a far more challenging target: intercontinental ballistic missiles. By 1955 efforts were under way to stretch the Nike system to meet this new enemy, the largest part of the scheme being the RCA/Sperry/General Electric ZAR (Zeus Acquisition Radar), which was the shape and almost the size of the Great Pyramid. It mounted a Luneberg lens receiver aerial which weighed over 1,000 tons but could not distinguish between re-entry vehicles (RVs) and decoys. To solve this problem, the world's first Discrimination Radar was developed to feed data to target- and missile-tracking radar which were upgraded versions of those used in the existing Nike systems. To enable it to intercept targets on ICBM trajectories hundreds of miles above the surface, the command-guided missile had a Thiokol tandem booster of unprecedented power, producing an enormous 204120 kg (450,000 lb) of thrust. Zeus was based aerodynamically on the Hercules, and was meant to carry a thermonuclear warhead fitted with a third-stage motor to guide its 'bus' to the point of interception.

Zeus was tested against Atlas RVs in 1960 but President Eisenhower had been advised that the computer systems were too slow to cope with the incredibly complex targeting problems presented by a mass ICBM attack, and that a new high-acceleration missile would have to be developed to deal with RVs which penetrated the main defences. He thus cancelled plans for operational deployment of Zeus, and it was not until 1963 that the Kennedy administration authorized the development of a new system called Nike X with new radars, and the exoatmospheric XLIM-49A Spartan and endoatmospheric Sprint missiles.

Specification

Nike Zeus

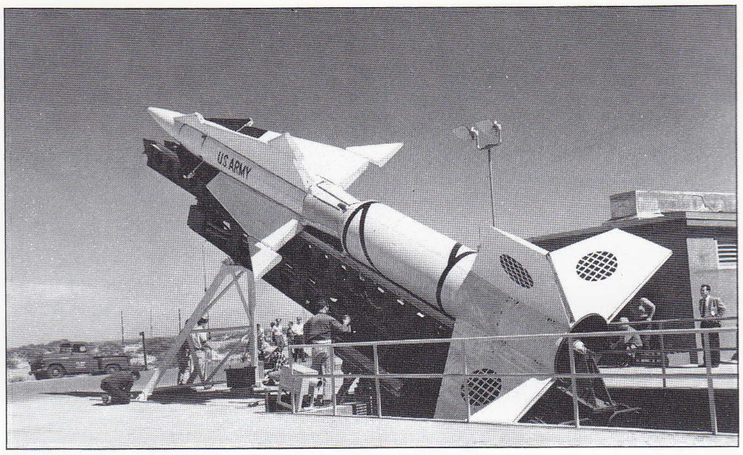
Type: very-long-range land-based anti-ICBM missile

Dimensions: length with booster 19.28 m (63 ft 3 in); diameter 1.52 m (5 ft 0 in); span 2.489 m (8 ft 2 in)

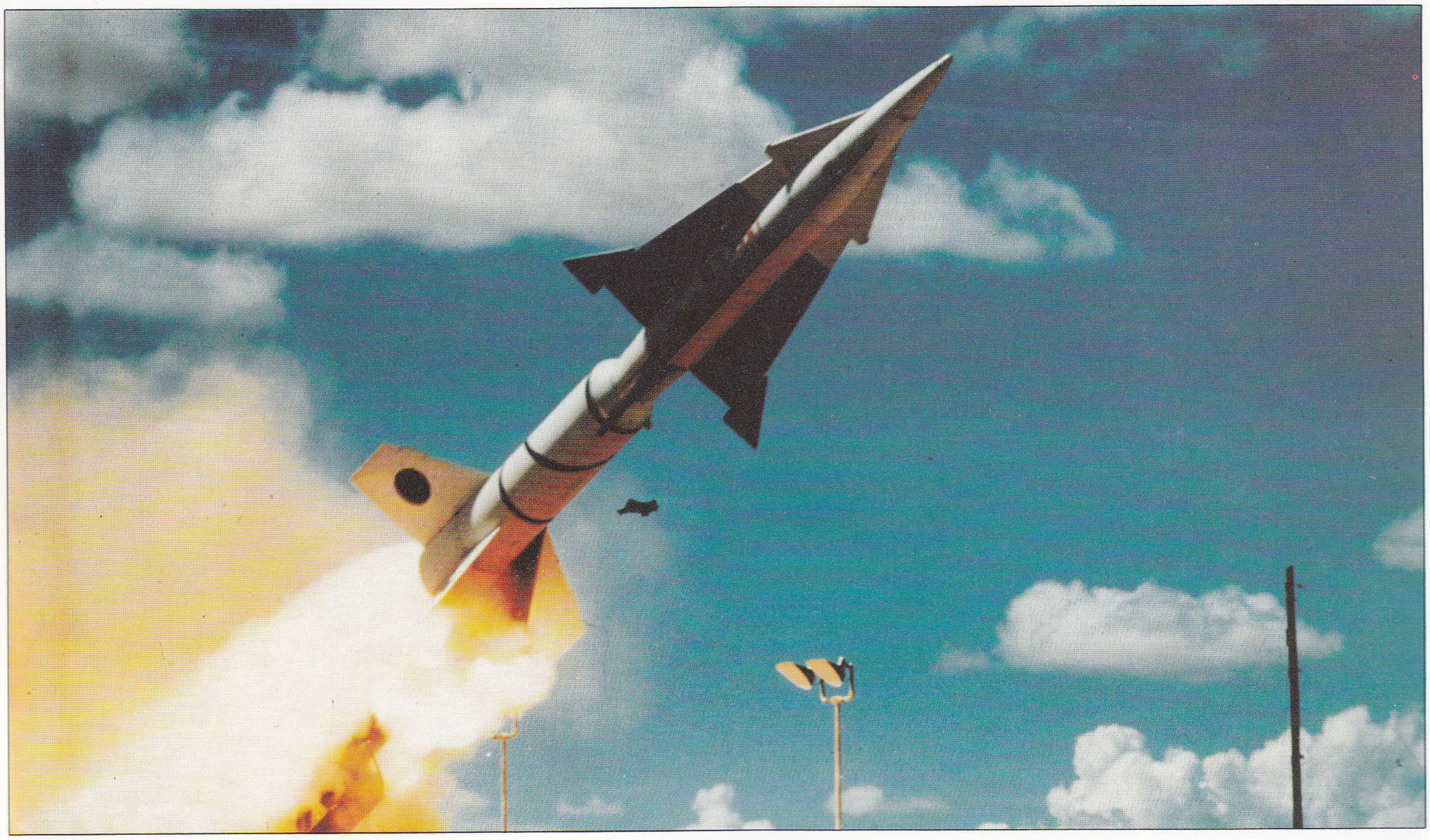
Launch weight: 18144 kg (40,000 lb)

Range: 402+ km (250+ miles)

Warhead: thermonuclear



Above: Nike Zeus was the last of the Nike system SAMs and was intended to deal not with enemy aircraft but Intercontinental Ballistic Missiles (ICBMs). It was propelled by a Thiokol booster of unprecedented power generating 204,120 kg (450,000 lb) of thrust.



Below: In 1960 Zeus was tested against incoming Atlas re-entry vehicles, but pessimistic advice from his advisers had persuaded President Eisenhower to cancel operational deployment leaving the Soviet Union as the only power to produce anti-ballistic missiles.

USA

Mauler

In 1958 the US Army identified a need for a mobile all-weather battlefield air-defence missile system able to intercept a variety of possible targets including missiles, rockets and tactical aircraft. Almost 100 companies were invited to a meeting and 31 design proposals were finally submitted. Convair-Pomona won the contract to produce a system mounted on a standard chassis containing all the fire-control equipment and a dozen **XMIM-46A Mauler** missiles, and able to fire accurately while moving. The unit was supposed to be light enough to be carried by a transport aircraft and even to be parachute dropped. In fact, in an amazingly retrograde step, the ambitious specifications were finally dropped after the missile had reached the hardware stage (cylindrical body with aft-mounted low-aspect-ratio cruciform wings trailed by rectangular cruciform control surfaces, indexed in line with the wings), and the decision made to accept a far less capable system which was more easily obtainable. Plans for an **XRIM-46A Sea Mauler** naval version also came to naught. Subsequently the US Army made to with Chaparral, spent over $1 billion on the unsuccessful Roland and is now looking at Rapier.

Specification

Mauler

Type: battlefield air-defence SAM

Dimensions: length 1.83 m (6 ft 0 in); diameter 127 mm (5 in); span 330 mm (13 in)

Launch weight: 54.4 kg (120 lb)

Range: 8 km (5 miles)

Warhead: HE

Project 'Bumblebee'

Most US Navy ship-launched anti-aircraft missiles are descended from a series of weapons, the development of which dates from the end of World War II. An astonishingly ambitious programme designed to prevent the Navy suffering from overwhelming air attack (such as had been inflicted upon it by kamikaze missions), Project 'Bumblebee' was to become one of the most influential missile programmes of all time.

USS Long Beach, *the first US Navy cruiser to be designed from the outset to operate guided missiles, was the first nuclear powered surface combatant in the world. It was originally equipped with both Talos and Terrier missiles (both being blooded off the coast of Vietnam).*

Today almost forgotten, the 'Bumblebee' research and development programme was one of the biggest and most far-reaching in history. Started in 1944, it eventually led to large families of surface-to-air missiles (SAMs) which protected US and friendly warships against air attack for 30 years, are still in production and will arm (for example) Australian warships ordered in 1986 and on which construction has not even begun!

During World War II the USA showed almost no interest in developing SAMs. The need was not for defensive missiles but offensive ones. Then, suddenly, the US and Allied ships closing in on Japan found themselves under terrifying attack from *kamikaze* suicide aircraft. Almost overnight work began on two guided missiles to protect the ships. These became KAN-1 Little Joe and KAY-1 Lark, both subsonic rockets steered by radio command, later Larks also having semi-active radar homing. Too late for the war, they did at least succeed in destroying Grumman Wildcat and Grumman Hellcat targets.

As early as August 1944 the US Navy recognized that what are today called SAMs were going to need a massive research and development effort, much bigger than one it could conveniently carry on 'in house'. The alternatives were giant contracts with industry or with technical leaders in the academic world, and the choice fell on the latter. The Navy Bureau of Ordnance picked the famed APL/JHU, the Applied Physics Laboratory of the Johns Hopkins University at Baltimore, Maryland. Here Dr Merle Tuve was charged with building up a team able to manage the 'Bumblebee Project'. Starting with a staff of 11, this was soon to employ as many thousand, as well as tens of thousands in industrial firms possessing the right skills in advanced technologies. In every respect the work thrust ahead beyond the frontiers of previous knowledge.

Inter-service rivalry

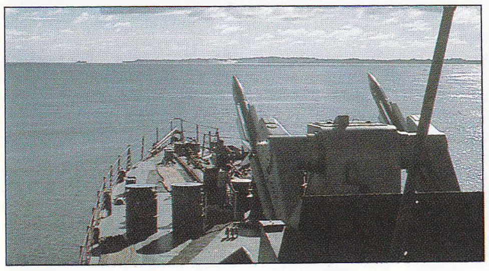
The US Navy was right to try to do the job properly, but it caused terrible trouble with the rival US Army. The US Navy's 'very aggressive program' was fought by the US Army Air Force at every opportunity. Expansion of the Naval Ordnance Test Station at Inyokern was bad enough, but when General H.H. Arnold learned in November 1945 of the planned $50 million missile test range at Point Mugu, California, he described it as 'a definite danger signal'; the USAAF fought the request for the $50 million. On top of the intense inter-service rivalry was the fact the US Navy was monopolizing the talented people who could work on missiles.

The basic brief handed to Dr Tuve was 'How do you best defend large surface warships against air attack?' This question was so vast and far reaching it was not surprising that the early contracts soon multiplied, and from mere paper studies (and there would have been computer simulations, had such things been invented) the work swiftly progressed to involve actual test hardware. Some of it was even made in the APL, though most was contracted to industry.

The questions needing answers were numerous. The BuOrd (Bureau of Ordnance) wanted SAMs far better in concept than Little Joe and Lark, which were rather crude subsonic aluminium and mild-steel-sheet beasts with poor power of manoeuvre and an effective range no greater than the existing 127-mm (5-in) guns. Ship radars, especially with aerials

A RIM-24 Tartar missile is launched from a nuclear-powered guided missile cruiser of the 'California' class. This development of the Terrier has semi-active radar homing, and is still in service with many navies nearly 35 years after the need for such a missile was expressed.

Seen being launched from the 'Leahy' class cruiser USS England *(CG-22), Terrier could be distinguished from Tartar by the long booster motor which gave the missile a much longer range than its contemporary and a much higher speed at burnout.*



Terrier, the first ship-launched surface-to-air missile to enter operational service, was developed using Talos technology. Some 8,000 rounds of this beam-riding missile were produced, and a 1-kiloton nuclear-armed version remains in service in a number of the Standard SM-2 armed vessels to this day.

mounted high above the sea, could see for scores of miles. Missiles could be made supersonic, and they ought to be able to outmanoeuvre any manned aircraft. Thus the basic task soon resolved itself into propulsion and guidance, though it also embraced structures, flight-control actuation and dynamics, and even the design of the magazines, loading systems and launchers in the ships. The scope of 'Bumblebee' was so large that soon hundreds of industrial and scientific contractors were involved. They were collectively known as Section T, and this led to the missiles that finally resulted all being given names beginning with this letter: Terrier, Talos, Tartar, Triton and Typhon.

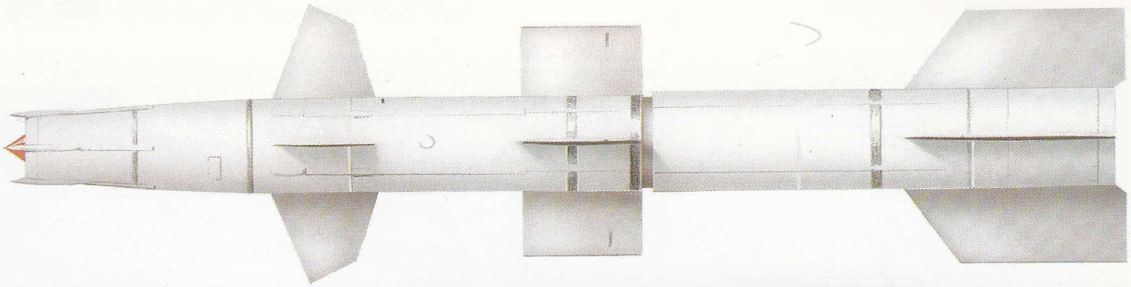
The original ball-park figures assumed were that, to meet the US Navy requirement, the missile should have an effective range of 320 km (20 miles) at 2900 km/h (1,800 mph) and this in turn led to a rough launch weight of 907 kg (2,000 lb) with a 'payload' of 272 kg (600 lb), which proved impossible to attain. By spring 1945 contracts had been let with M.W. Kellogg Company and Allegany Ballistics for large solid rocket motors, and with Bendix for the fuel metering system for an advanced supersonic ramjet. By late 1949 detailed engineering design was in progress of the first two SAMs, together with the associated ship handling gear and large radars. The bigger of the two was the SAM-N-6 Talos, with an integral ramjet burning kerosene or kerosene/naphtha and fed by a nose inlet looking like an advanced MiG-21. Radio aerials round the nose picked up radar signals reflected from the target and homed the missile under the control of four moving wings arranged round the body amidships. Complete with its enormous tandem boost rocket even the first Talos weighed nearly 2722 kg (6,000 lb), but it went four times as far as the 32 km (20 miles) stipulated. It led to a large family of later Talos missiles, as described separately.

The initial all-rocket SAM was the SAM-N-7 Terrier. This was naturally much more slender, and shorter-ranged. The first Tactical Prototype was assembled in November 1949 and fired at the Naval Ordnance Test Station, China Lake, on 16 February 1950. After a massive development programme this led to the BW-1 production missile of late 1953. It had sharply tapered, pointed wings amidships, looking like small editions of those of Talos, and these small wings and the rather quick burnout of the sustainer motor meant that manoeuvrability deteriorated at distances beyond about 19.3 km (12 miles). Nevertheless it was a workable system, which completed sea trials from the battleship USS *Mississippi* in 1954 and finally became operational (the first ship-to-air missile in the world) in 1956, aboard the cruisers USS *Boston* and *Canberra* and the destroyer USS *Cyatt*. From it stemmed the neat Tartar, which has no boost motor and which is still being adopted for new ships despite its 40-year ancestry.

The ultimate SAM to be developed in the 'Bumblebee Project' was not unnaturally the SAM-N-8, given the odd name of Typhon. This is described separately. Almost inevitably, the Typhon (a missile with capability far exceeding anything possesssed by any ship of the US Navy today) is now almost forgotten. So, too, is the biggest of all the 'Bumblebee' offspring, the XSSM-N-4 Triton. This was basically a scaled-up Talos, with a body of 1.52-m (60-in) diameter and 13.7 m (45 ft) long. When cancelled in 1955 this amazing cruise missile even had inertial guidance with a map-matching system like that used today!

USA

Talos



Above: Talos was the area defence component of the 'T' series missiles developed under the auspices of Project 'Bumblebee'. A large, ramjet-powered vehicle, it was originally designated SAM-N-6 (later to become RIM-8).

The US Navy's interest in developing SAMs stemmed from its disagreeable experience of Japanese *kamikaze* attacks in the last 12 months of World War II. The **SAM-N-6 Talos** was one of a series of missiles which originated in a research programme bearing the codename 'Bumblebee'. After prolonged development, the cylindrical missile (with pivoting cruciform wings and fixed cruciform tail surfaces) entered service in 1958, saw action during the Vietnam War and was still being used in the early 1980s, although only as a supersonic target for other missiles.

Talos was fired from a stabilized twin launcher, powered for the first 2.2 seconds of flight by a Kellogg/Allegany Ballistics Laboratory solid-propellant booster which set records during the 1950s. After burnout, this separated by air drag. The integral Bendix ramjet burned a mixture of naptha and kerosene, expelled by nitrogen into a turbine pump and combustion section: a pitot head in the nose fed data to vary the fuel flow to maintain a constant missile speed of Mach 2.5 despite variations in drag. The missile was gathered in the SPG-56's tracking beam and controlled via the beam-riding receiver until it closed with the target. At this point the shipboard SPG-49 target-illuminating radar picked up the target and the Talos homed semi-actively on the target reflections picked up by the four probe aerials positioned around its nose.

Talos achieved operational status in 1958 when the **SAM-N-6B** was fitted to the cruiser USS *Galveston*, which fired its first live round at sea on February 24 1959. In 1962 the type was redesignated **RIM-8**. Several Talos-armed vessels were in action off Vietnam: USS *Long Beach* shot down two North Vietnamese MiGs at extreme range in 1968. Initially a pulse homing system **(RIM-8F)**, the Talos was modified during the mid-1960s to continuous wave operation (**RIM-8E, RIM-8G** and **RIM-8J**). A number were converted to **RGM-8H** surface-to-surface anti-radar missiles, and during the 1970s older models were altered to **MQM-8G Vandal** targets, used to simulate anti-ship missiles.

Specification

RIM-8J Talos

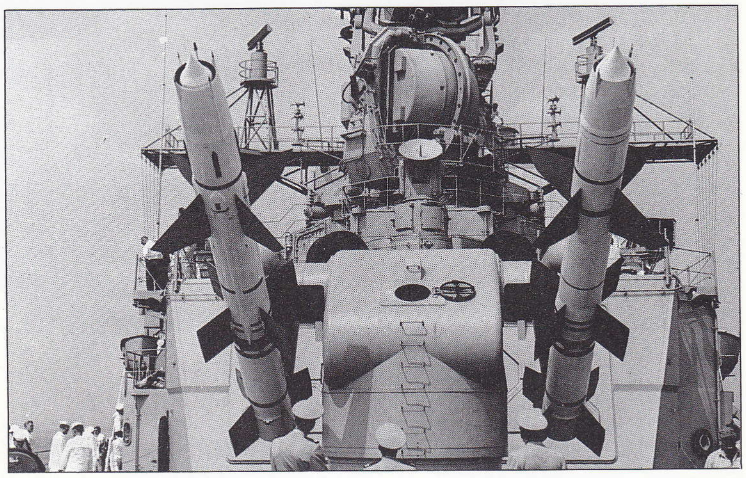
Type: long-range ship-borne area-defence SAM

Dimensions: length (missile) 6.78 m (22 ft 3 in) and (total round) 9.91 m (32 ft 6 in); diameter 762 mm (30 in); span 2.90 m (9 ft 6 in)

Launch weight: (missile) 1590 kg (3,505 lb) and (total round) 3540 kg (7,805 lb)

Range: about 120 km (75 miles)

Warhead: nuclear or HE with a proximity fuse



USS Long Beach *shot down two North Vietnamese MiG-17s at extremely long range during 1968, and attacked enemy aircraft on five other occasions with Talos missiles. These missiles are seen here on the converted World War II cruiser USS* Little Rock.

USA

Typhon

The series of missiles spawned by the 'Bumblebee' programme (Talos, Tartar and Terrier) required the attention of a dedicated guidance beam generator throughout their flight, and no increase in rate of fire was possible if the system was faced with a saturation attack. To overcome this problem it was decided to develop a combination of command and terminal guidance which after a 20-year programme has eventually become AEGIS. Another consideration was the sheer cost of shipboard electronics, which was beginning to dictate the overall cost of warships. An area-defence ship capable of engaging a multitude of incoming missiles might replace several vessels fitted with earlier systems. This spurred the development of the **SAM-N-8 Typhon** in the 1950s.

Typhon's unified weapon-control system was to incorporate a Westinghouse fixed-array multi-element tracking and guidance radar to provide the high power necessary for target acquisition and illumination for long-range interception plus the beam agility required to engage multiple targets. The active radar homing Typhon was expected to tackle such targets as very-high-altitude bombers, or missiles approaching at Mach 3, or free-fall bombs, or rockets travelling at Mach 4 as well as surface targets the size of a cruiser. Two models were planned, a medium-range **RIM-55A** and a long-range **RIM-50A**, both with optional nuclear or conventional warheads. The latter had about twice the range of Talos and was much faster (Mach 5 compared with Mach 2.5) but the missile weighed only half as much and its warhead was reduced proportionately to 68 kg (150 lb), giving a lethal radius of 15.2 m (50 ft). The former flew at Mach 1.25 to Mach 4 and had a range similar to that of the Tartar. Design was similar to that of the earlier types, with a jettisonable solid-propellant booster behind the missile proper, which was powered by a Bendix integral ramjet in the cylindrical body with a central shock-cone in the nose. The aerodynamic surfaces were different, however, being cruciform long-chord wings of low aspect ratio fitted with tip extensions for control.

Typhon sounded extremely impressive, but so too had the first three 'T' missiles. In service all had proved disappointingly unreliable: a 1962 survey of six Tartar-armed ships found they averaged only 30 per cent readiness compared with the theoretical 90 per cent. By this time the US Navy had spent a fortune on missile ship construction (approximately $6.5 billion) and the wisdom of embarking on a fourth 'T' type system was questioned. What was the point of developing an increased raid-handling capability when the existing systems were still unable to deal with their supposed targets? Furthermore, there was unease at the 'eggs in one basket' nature of Typhon: was it desirable to concentrate so high a proportion of a surface force's air defence in a single system in a single ship? These reservations, combined with the inadequacies of the 'T' series so far, combined to kill the Typhon programme, Secretary of Defense McNamara cancelling it in December 1963. Much of the budget allocated for Typhon went instead towards rectifying the faults of the existing missiles.

Specification

RIM-50A Typhon

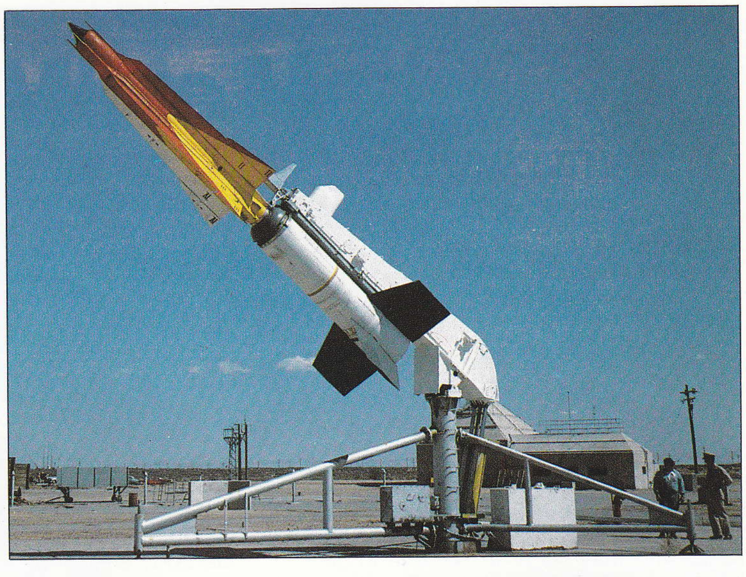
Type: very-long-range ship-borne area-defence SAM

Dimensions: length (missile) 8.53 m (28 ft 0 in) and (with booster) 14.02 m (46 ft 0 in)

Launch weight: about 9072 kg (20,000 lb)

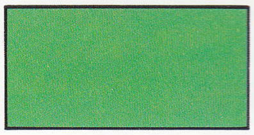
Range: 322 km (200 miles) at Mach 5

Warhead: nuclear or HE

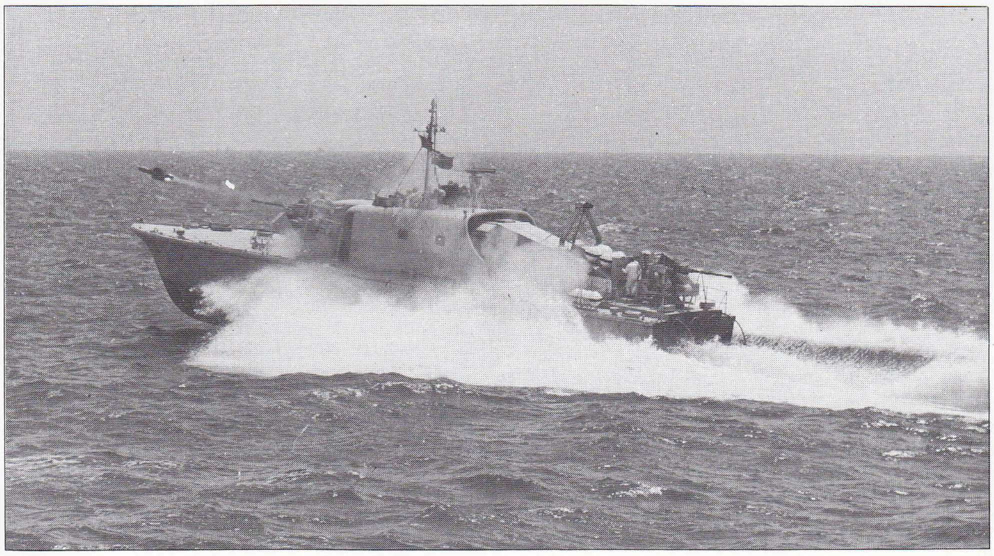


Typhon was to have been the ultimate member of the 'T' series of naval SAMs spawned by the 'Bumblebee' project, but the failings of the earlier missiles led to Typhon's cancellation, the money being spent on rectifying the problems of its predecessors.

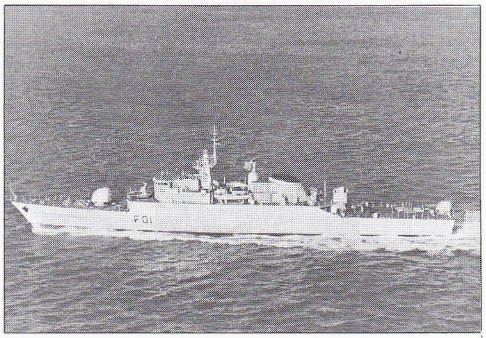
Libya



Although one of the wealthiest countries in North Africa as a result of its oil resources, Libya is also one of the smallest in terms of population (3.55 million) as the major part of its land area is arid in nature. This combination should have dictated armed forces sized merely for defensive purposes. However, the political aspirations of its leader, Colonel Qadhafi, have turned the country into a major centre for terrorism and unrest in the Middle East and Africa. Libyan troops, tanks, aircraft and agents provocateurs have been directly involved in the recent Chadian civil war, the 1978 border war between Tanzania and Uganda, the brief but bloody border war with Egypt in 1977 and the various internal struggles in Sudan, Tunisia, Egypt, Morocco and Lebanon. In addition, provocative actions against American military aircraft and ships in the international waters and airspace over the Gulf of Sirte resulted in the now-famous air battle of 19 August 1981 when two Soviet-supplied Sukhoi Su-22 'Fitter-J' ground-attack fighters challenged two US Navy carrier-based Grumman F-14A Tomcats and were shot down for their troubles. These actions, and the vast amount of armaments purchased in recent years, have earned Libya the distrust of practically all her near neighbours and have resulted in the country being almost permanently in a state of tension as diverse internal uprisings by political opponents of Qadhafi are put down with ruthless efficiency by his intelligence and security units. The killing of the regime's opponents has also spread to the streets of a number of European cities.



Under the idiosyncratic regime of Colonel Qadhafi, Libya has earned the complete mistrust of her neighbours and worldwide notoriety. Nevertheless, she is wealthy and has little trouble procuring weapons. This British-built FAC was recently overhauled in Italy.



Vosper Thornycroft delivered the frigate *Dat Assawari* ***to Libya in 1973 and she had an extensive refit at Genoa, Italy, 10 years later. The Libyan navy continues to expand rapidly.***

The Army

The 58,000-man Libyan army has only two major units, which have a varying number of smaller formations placed under command as required. A full listing is:

one mechanized divisional HQ,
20 tank battalions,
30 mechanized infantry battalions,
one national guard brigade,
two special forces brigades (with 10 battalions),
10 field artillery battalions,
two air-defence artillery battalions,
two air-defence SAM regiments,
nine air-defence SAM battalions, and
two surface-to-surface missile brigades.

For use in its African adventures the army can call upon the paramilitary Islamic Pan-African League of some 7,000 men organized into one armoured, one mechanized infantry and one para-commando brigade. This force uses equipment such as tanks, APCs and artillery from the large reserve stocks available.

The equipment used by the army is a mixture of Eastern and Western types characterized in the main by its modernity. Western countries which have supplied Libya in return for oil and large cash payments over the years include Brazil, France and Italy, although it is known that samples of the weapons supplied have been passed to the USSR, Libya's other major arms supplier, for testing. A full list of the weaponry currently in service is:

Armour: T-34/85, T-54, T-55, T-62, T-72 and T-74 MBTs; Shorland internal security vehicles; EE-3 Jararaca reconnaissance vehicles; BRDM-1, BRDM-2, Saladin Mk 2 and EE-9 Cascavel armoured cars; and BMP-1, BTR-50, BTR-60, OT-62, OT-64, EE-11 Urutu, Chaimite, Saracen, M113A1 and Fiat 6614 APCs;

Artillery: (towed) 105-mm (4.13-in) M101 howitzer, 122-mm (4.8-in) D-30 howitzer, 122-mm D-74 gun, 130-mm (5.1-in) M46 gun, 152-mm (6-in) D-20 gun/howitzer, 155-mm (6.1-in) M114 howitzer, and 180-mm (7.09-in) S-23 gun;

(self-propelled) 122-mm ISU-122 SP gun, 122-mm 2S1 SP howitzer, 152-mm ISU-152 SP gun, 152-mm 2S3 SP howitzer, 152-mm DANA SP gun, 155-mm Palmaria SP gun, and 155-mm M109 SP howitzer;

(MRLs) 107-mm (4.2-in) Type 63, 122-mm BM-21, 122-mm RM70, 130-mm M51, and 300-mm (11.8-in) Astros II;

(mortars) 81-mm (3.2-in) M1, 82-mm M37, 120-mm (4.7-in) M43, 160-mm (6.3-in) M43, 160-mm M160, and 240-mm (9.45-in) M240; and

(SSMs) FROG-7 and 'Scud-B';

Anti-armour weapons: RPG-7 rocket-launchers; 73-mm (2.87-in) SPG-9, 82-mm (3.2-in) B-10, 106-mm (4.17-in) M40A1 and 107-mm B-11 recoilless rifles; Vigilant, 'Sagger' (including BRDM-2 installations), 'Spigot' and Milan ATGWs;

Anti-air weapons: (towed) 14.5-mm (0.57-in) ZPU-1, 2 and 4, 23-mm ZU-23, 40-mm Bofors L/70, 40-mm Breda L/70 and 57-mm S-60 guns;

(self-propelled) 23-mm ZSU-23-4 and 30-mm M53/59 guns; and

(SAMs) SA-4 'Ganef', SA-6 'Gainful', SA-7 'Grail', SA-8 'Gecko', SA-9 'Gaskin', SA-13 'Gopher' and Crotale; and

Small arms: 9-mm Beretta M951 pistol; 9-mm Beretta M12 and 9-mm Sterling L34 SMGs; 5.56-mm M16A1, 7.62-mm FN-FAL, 7.62-mm BM-59, 7.62-mm AK-47 and 7.62-mm AKM rifles; and 7.62-mm FN-MAG, 7.62-mm RPD, 7.62-mm RPK, 7.62-mm PK, 12.7-mm DshK and 0.5-in Brownings MGs.

Of the 2,500 MBTs held in the Libyan inventory, some 1,400 (as well as considerable amounts of other equipment) are held in vast war reserve stocks located in interior desert areas. To use these weapons there are only 40,000 men in the People's Militia. The supposition thus raised is that these weapons could be a Soviet prepositioned stockpile for use in a wide-ranging conflict.

The Navy

The 6,500-strong Libyan navy is similar to the army in having the best from both East and West. The major open-water offensive capability is provided by six newly-built Soviet 'Foxtrot' class diesel-electric submarines delivered from 1976 onwards, whilst coastal and covert operations are handled by at least six two-man Yugoslav-built 'Mala' class midget submarines.

The surface fleet has only one major combatant, the Vosper Thornycroft frigate *Dat Assawari*, which has recently been refitted in Italy to carry four Otomat long-range SSMs and an Albatros quadruple SAM launcher. The main missile punch, however, is provided by the light forces, which have four Soviet 'Nanuchka' class (each with four SS-N-2B 'Styx' SSMs) and four Italian 'Assad' class (each with four Otomat SSMs) missile corvettes, 10 French 'La Combattante IIG' class (each with four Otomat SSMs), three British 'Susa' class (each with 16 SS.12 wire-guided missiles) and 12 Soviet 'Osa II' (each with four SS-N-2B 'Styx' SSMs) missile craft. These are assisted by the gun-armed corvette *Tobruk* and some 22 large patrol and fast attack craft, some of which are seconded to the customs service.

For amphibious warfare work there is a single naval infantry battalion, although some army units

12 PASS

are believed to be also trained in assault landings. These use two French 'PS700' class LSTs, three Soviet 'Polnochny-C' class LSMs and up to 50 Turkish-built 'C107' class LCTs.

A limited mine countermeasures and minelaying capability is provided by seven Soviet 'Natya' class ocean-going minesweepers. In the laying role they are joined by two roll-on/roll-off ferries, the *Gnat* and *El-Timsah*, and the four 'Assad' class corvettes. It is now fairly certain that the *Gnat* was solely responsible for the recent minelaying in the Red Sea which caused severe damage to a number of merchant ships including several from Libya's major ally, the USSR. There are also some dozen auxiliary vessels of various types, plus the LSD-type logistic support ship *Zeltin*, which is used mainly as a HQ ship and tender for the light forces.

The Air Force

The Libyan air force (Al Quwwat Alijawwiya Al Libiyya) has (like the army) much of its first-line equipment in store as a result mainly of aircrew shortages or lack of spares. Flying a mix of Soviet and French combat aircraft, the 8,500-man service uses pilots and groundcrew from Pakistan, Syria, North Korea, the PLO, the mercenary market and the USSR in an effort to overcome its personnel shortcomings.

A single squadron with seven Tupolev Tu-22 'Blinder-A' bombers and two 'Blinder-C' conversion trainers provides the nation's medium attack potential, and has seen action in several of Libya's African conflicts. Sufficient 'Blinders' are believed to be in store to create a second squadron if required.

The interceptor force has three squadrons and an OCU which has access to some 40 Dassault-Breguet Mirage F.1EDs and six F.1BDs, 140 Mikoyan-Gurevich MiG-23 'Flogger-Es' and 14 'Flogger-Cs', 50 MiG-25 'Foxbat-As' and five 'Foxbat-Cs' and 55 MiG-21 'Fishbed-Js'. Ground-attack and counter-air missions are handled by six squadrons and an OCU with around 18 MiG-23 'Flogger-Fs', some 100 Sukhoi Su-20/22 'Fitter E/F/Js', 30 SOKO J1-A-E Jastrebs and the remnants of 14 Mirage F.1AD-200s, 53 Mirage 5Ds, 32 Mirage 5DEs and 15 Mirage 5DDS supplied by France. A single reconnaissance unit flies the survivors of 10 Mirages 5DRs, although the Soviets are believed to have supplied a small number of MiG-25 'Foxbat-B' photo-reconnaissance and 'Foxbat-D' Elint aircraft for mutual use in the region.

During the 1977 border war with Egypt some aerial combat was undertaken without much success, and a number of aircraft were lost in dogfights and to Egyptian air force counter-air strikes on the Mirage bases.

The territorial expansion plans by Qadhafi, and his meddling in neighbours' affairs are reflected in the 10 squadrons of fixed-wing transports and helicopters. The two heavy-lift fixed-wing units fly five Antonov An-26 'Curl', seven Lockheed C-130H Hercules, 20 Aeritalia G.222L, nine Ilyushin Il-76 'Candid', two Canadair CL-44, eight Fokker F.27-600 Friendship and 10 Let L-410UVP Turbolet transports. (There are another 11 'Candids' in Libyan airline service, and these are also regularly used on military duties.) Five of the helicopter squadrons use mainly transport types including 19 Italian-built Boeing-Vertol CH-47C Chinooks, 20 or so Mil Mi-8 'Hip-Cs', two Agusta-Bell AB.212s, five Agusta-Bell AB.206s, 10 Aérospatiale SA.316 Alouette IIIs, nine Agusta-Bell AB.47s and a few newly-arrived Aérospatiale SA.342 Gazelles. The sixth squadrons is of regimental size and flies some 30 Mi-24 'Hind-D' gunships in the anti-armour/ground support role. The last two squadrons are tasked exclusively with naval support duties flying 12 Mi-14 'Haze-A' ASW and eight Aérospatiale SA.321 Super Frelon ASW/SAR helicopters respectively from the naval air station at Misratah.

A significant training programme has been initiated with four squadrons for the rapid build-up of indigenous flying personnel numbers in the air force, and to provide such training for subversive elements like the PLO. The units fly some 230 Italian SIAI-Marchetti SF.260WL and SF.260ML primary and basic piston-engined trainers, 60 Yugoslav SOKO G2-A-E Galeb and 160 Czech Aero L-39ZO basic and advanced jet trainers, and 20 Mi-2 'Hoplite' helicopters. Many of these aircraft can also double in the light attack/COIN roles, and have been used as such in limited local wars where sophisticated air defences are unlikely to be encountered.

The air force also operates its own air-defence network with three brigades and two battalions of SA-2 'Guidelines', SA-3 'Goas' and Crotales. The recent delivery of several battalions of the ultra-long-range SA-5 'Gammon' by the Soviets (to cover the Egyptian border and the Gulf of Sirte) is believed to be a political gesture to the Libyans, and the weapons may well be used in further stage-managed incidents with the Americans.

Oil revenue can buy expensive aircraft but cannot create air crew, and much of Libya's ultra-modern air force is grounded for lack of men or spares. Mercenaries, Syrians and Pakistanis supplement Libyan pilots flying aircraft like this Sukhoi Su-17.